d·i·e

Deutsches Institut für Entwicklungspolitik

German Development Institute

Discussion Paper 25/2013

Challenges in Measuring the State of the Environment in Developing Countries

A Literature Review

Katharina M. K. Stepping

Challenges in measuring the state of the environment in developing countries

A literature review

Katharina M. K. Stepping

Bonn 2013

Discussion Paper / Deutsches Institut für Entwicklungspolitik
ISSN 1860-0441

Die deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data is available in the Internet at http://dnb.d-nb.de.

ISBN 978-3-88985-608-1

Katharina M. K. Stepping is a researcher at the German Development Institute / Deutsches Institut für Entwicklungspolitik (DIE), in the department "Environmental Policy and Management of Natural Resources".

E-mail: katharina.stepping@die-gdi.de

Tulpenfeld 6, 53113 Bonn
☎ +49 (0)228 94927-0
🖷 +49 (0)228 94927-130
E-Mail: die@die-gdi.de
www.die-gdi.de

Abstract

A decent environmental quality is a necessary condition for survival of humankind in general and human development in particular. Environmental pollution is a great challenge in developing countries, where especially the poorest are most likely to suffer. Reflecting the state and the dynamics of the environment is essential for science and policy advice. Environmental indicators capture the physical, biological or chemical characteristics of the environment. Environmental composite indicators merge several environmental indicators in order to summarise the multifaceted state of the environment at national level into one single score. These composite indicators allow for cross-country comparisons.

The analysis here includes four cross-country composite indicators: the Environmental Vulnerability Index, the Environmental Performance Index, its predecessor the Environmental Sustainability Index and the Ecosystem Wellbeing Index. In addition, the dimension Environmental Wellbeing of the Sustainable Society Index and the Living Planet Index are analysed. Currently, the latter has mainly been constructed at a global scale with only limited availability at national level.

The principal questions addressed in this paper are: What cross-country environmental composite indicators exist? To what extent are they suited to measuring the state and the dynamics of the environment? and, How useful are they for developing countries?

This analysis is the first comprehensive comparison of cross-country environmental composite indicators, evaluating their conceptual and methodological strengths and weaknesses. The conceptual assessment focuses on content-related aspects. It evaluates whether the individual indicator is an appropriate approximation suited to reflect dimension and composite, respectively. The technical assessment focuses on technical issues of constructing a composite indicator such as imputation of missing data, normalisation, weighting and aggregation as well as coherence. Third, the analysis evaluates how useful these environmental indices are within the context of developing countries.

Acknowledgements

The author extends warm thanks to Ines Dombrowsky, Markus Loewe, Elke Herrfahrdt-Pähle and Waltina Scheumann for helpful comments and suggestions on earlier drafts. I am also indebted to Michaela Saisana from the Joint Research Centre of the European Commission in Ispra, Italy, who provided very useful comments. Seminar participants at the DIE workshop on measurement and at the e-Frame workshop on environmental indicators in Venice, Italy, offered helpful advice. I am grateful to Hanna Schmole for excellent research assistance.

Bonn, December 2013 Katharina M. K. Stepping

Contents

Annex

Figures

Tables

Abbreviations

BOD	Biochemical oxygen demand
CEI	Core Environmental Indicators
CEPIA	Country Environmental Policy and Institutional Assessment Indicator
CO_2	Carbon dioxide
CH_4	Methane
CPIA	Country Policy and Institutional Assessment
CSD	Commission on Sustainable Development
DCs	Developing countries
DEA	Data envelopment analysis
DJSGI	Dow Jones Sustainability Group Index
DPSIR	Driving force-pressure-state-impact-response
DSR	Driving force-state-response
EDI	Environmental Degradation Index
EEA	European Environment Agency
EF	Ecological footprint
EPI	Environmental Performance Index
ESI	Environmental Sustainability Index
EVI	Environmental Vulnerability Index
EWI	Ecosystem Wellbeing Index
FEEM	Fondazione Eni Enrico Mattei
GDP	Gross domestic product
GEF	Global Environment Facility
GEO	Global Environmental Outlook
GHG	Greenhouse gas emissions
GMO	Genetically-modified organism
HDI	Human Development Index
HFC	Hydrofluorocarbon
HWI	Human Wellbeing Index
IMF	International Monetary Fund
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre (European Commission)
KEI	Key environmental indicators
kWh	Kilowatt-hour
LPI	Living Planet Index
MDG	Millennium Development Goal
NOx	Nitrogen oxides
NO_2	Nitrogen dioxide
N_2O	Nitrous oxide
OECD	Organisation for Economic Co-operation and Development
PCA	Principal component analysis
PFC	Perfluorocarbon
PPP	Purchasing power parity
PSR	Pressure-state-response

SEI	Sectoral environmental indicators
SF_6	Sulphur hexafluoride
SO_2	Sulphur dioxide
SOPAC	South Pacific Applied Geoscience Commission
SSI	Sustainable Society Index
TSP	Total suspended particulates
UN	United Nations
UNSD	UN Statistics Division
UNEP	United Nations Environment Programme
VOC	Volatile organic compounds
WSI	Wellbeing/Stress Index
WWF	World Wildlife Fund

1 Introduction: Why is it important to measure the state of the environment?

The sustainable use of natural resources and sink capacities is one of the key challenges for developed and developing countries in the 21st century. Climate change, biodiversity loss and the degradation of ecosystems threaten current and future possibilities for human development. It is feared that the overexploitation of natural resources and sink capacities will lead to crucial tipping points of the earth's ecosystem which may trigger abrupt and non-linear environmental changes, with potentially dramatic consequences for humankind (Rockström et al. 2009). Particularly in developing countries, many citizens are very vulnerable and sensitive to environmental degradation as they earn their living from agriculture, for instance, or live in densely populated urban slums. Both developed and developing countries need strategies to cope with these environmental challenges that already have economic, social and political consequences which are likely to worsen in the future. The discussion about a transition to a green economy recognises the complexity and urgency of the matter (OECD 2011; UNEP 2011; WBGU 2011; World Bank 2012), picking up on earlier requests of sustainable development (Meadows et al. 1972). Measuring the status quo and the progress to a green economy requires indicators for human well-being, social equity, environmental risks and ecological scarcities (Bassi / Fulai 2012). Yet, current accounting conventions for national income do not take into account the depletion of natural resources, nor do they adjust for degradation of environmental amenities but count activity to compensate environmental damage as part of income (Perman et al. 2011).

Any strategy to cope with these environmental challenges needs to define objectives and measure the progress towards these objectives by tracing changes over time. Environmental indicators, such as sulphur dioxide emissions, biochemical oxygen demand or extent of forest, quantify a single dimension of the state of the environment in numerical scores. Composite environmental indicators, however, are able to measure the state of the environment in its multiple dimensions. They aggregate several weighted environmental indicators into an index, with the weights expressing the theoretical importance of each indicator. As they measure environmental conditions at a particular point in time at national level, the score reflects the country average. If initial conditions are controlled for in composing the index, cross-country comparison is possible. If environmental conditions are measured repeatedly, relative changes over time within a country and between countries can be assessed.

This analysis provides a cross-country comparison of environmental composite indicators from a conceptual and statistical perspective. It also evaluates their usefulness for measuring the state of the environment in developing countries. To date, there has been no systematic, comprehensive study of such indices with a focus on developing countries. The analysis addresses three key questions: What cross-country environmental indices exist? To what extent are they suited to measuring the state of the environment? and, How useful are they for developing countries? The purpose of this research is to evaluate cross-national environmental indices and assess their validity and potential biases in order to identify methodologically robust approaches. Variables and indicators will be analysed at disaggregate level where appropriate. A comprehensive evaluation of all variables and indicators, however, is beyond the scope of this study.

The study includes six environmental composite indicators that were selected based on five criteria.[1] First, the selected composite indicator is *relevant* because it measures a facet of the environment at the country level. Second, the composite indicator *quantifies* the facet of the environment in numerical scores at national level and allows for cross-country comparisons. Third, information about the composite indicator is *accessible* on the internet in English. Fourth, the methodology of the composite indicator is *transparent*. Fifth, the composite indicator *covers* several developed and developing countries.

The analysis is structured as follows: After the introduction, Section Two presents the main challenges in producing cross-country environmental indices. Section Three reviews the theoretical framework and assesses the strengths and weaknesses with regard to content, technique and country coverage of available cross-country environmental indices. Section Four compares these strengths and weaknesses. The paper concludes with a discussion of the findings. Appendix A provides an overview about three environmental indicators and several indicator sets, alternative sources of useful information. Appendix B compares the environmental indicators, while Appendix C compares the indicator sets. Appendix D details the coverage of environmental spheres and related aspects for all indices, indicators and indicators sets included in the analysis. Appendix E presents the geographical coverage of developing countries for the environmental indices and indicators.

2 Composite indicators: Why is it challenging to produce cross-country environmental indices?

Environment statistics describe the state and trends of the environment. They cover environmental media, the biota within the media, and human settlements (OECD 2012a). Environment statistics use indices and indicators to adequately portray human and environmental conditions. Environmental indicators commonly reflect the state and the dynamics of the environment. They typically include physical, biological or chemical indicators about the natural environment (Smeets / Weterings 1999) and can often be classified into indicators of environmental pressures, environmental conditions and societal responses (Linster 2003, see also 2.1). Environmental indicators are useful for measuring environmental quality, environmental pollution or environmental degradation. Environmental indicators are useful to isolate key aspects of the environmental conditions and trends (Niemeijer 2002) because several indicators or an index are needed to capture the condition of complex environmental systems. By definition, indices are *"measure(s) of an ab-*

1 Note that the Living Planet Index (LPI) is included in this study, although it is primarily available at global level. Nevertheless, national LPIs were calculated for Norway, Canada and Uganda.
Note that the Sustainable Society Index (SSI) measures the environment in one of its dimensions, but not the index as such. The FEEM Sustainability Index also measures the environment in one of its dimensions; it was not included, however, because it is a model-based index that simulates future trends of each indicator – looking into the future (FEEM 2013).
Note that the evaluation does not include the Environmental Degradation Index (EDI), based on several indicators on environmental degradation or pollution. The indicators are annual per capita fresh water withdrawals; printing and writing paper consumed per capita; per capita CO_2 emissions; and share of world CO_2. Using principal components analysis (PCA), the scores for 174 countries are obtained by combining the raw variables with weights proportional to their component loadings (Jha / Murthy 2006).

stract theoretical construct in which two or more indicators of the construct are combined to form a single summary score" (Carmines / Woods 2004, 485).

Composite indicators or indices can convey highly condensed information and facilitate the representation of an underlying multidimensional concept.[2] In their construction, information on single indicators is selected, weighted and combined. *"A composite indicator is formed when individual indicators are compiled into a single index on the basis of an underlying model."* (OECD 2008, 13).[3] The great advantage of a composite indicator is that it can summarise complex concepts into a single index. Yet, if it is poorly constructed or misinterpreted, this may provoke simplistic analytical conclusions. Hence, composite indicators or indices condense the amount of information considerably but pose conceptual and methodological problems related to normalisation, weights, and aggregation. It is hence crucial to keep in mind the one limitation: A composite indicator is primarily suitable to initiating discussion and to awakening public interest – but it is much less suitable for drawing direct policy conclusions (OECD 2008).

Table 1 summarises the main pros and cons of constructing and using composite indicators. On the one hand, a soundly constructed composite indicator has huge advantages compared to a battery of separate indicators. On the other hand, the critical precondition is that the composite indicator is constructed in a transparent manner, based on sound theoretical and conceptual principles. In the end, the quality of the framework and the data used is crucial for both the quality of the composite indicator and the soundness of its messages (OECD 2008).

Table 1: Pros and cons of composite indicators or indices

Pros	Cons
– summarize complex, multidimensional concepts – easy interpretation – assess progress over time (e.g. countries) – reduce visible size of a set of indicators – include more information within the existing size limit – facilitate communication with politicians and general public and promote accountability	– may result in simplistic policy conclusions, if poorly constructed or misinterpreted – may be misused, if poorly and/or intransparently constructed – selection of indicators and weights may be subject to debate – may disguise failings, if intransparently constructed

Source: Adapted from OECD (2008); based on Saisana and Tarantola (2002, 5)

Figure 1 illustrates some basic definitions for the sake of clarity. The *composite indicator* or *synthetic indicator* is the aggregate of all dimensions, objectives, individual indicators

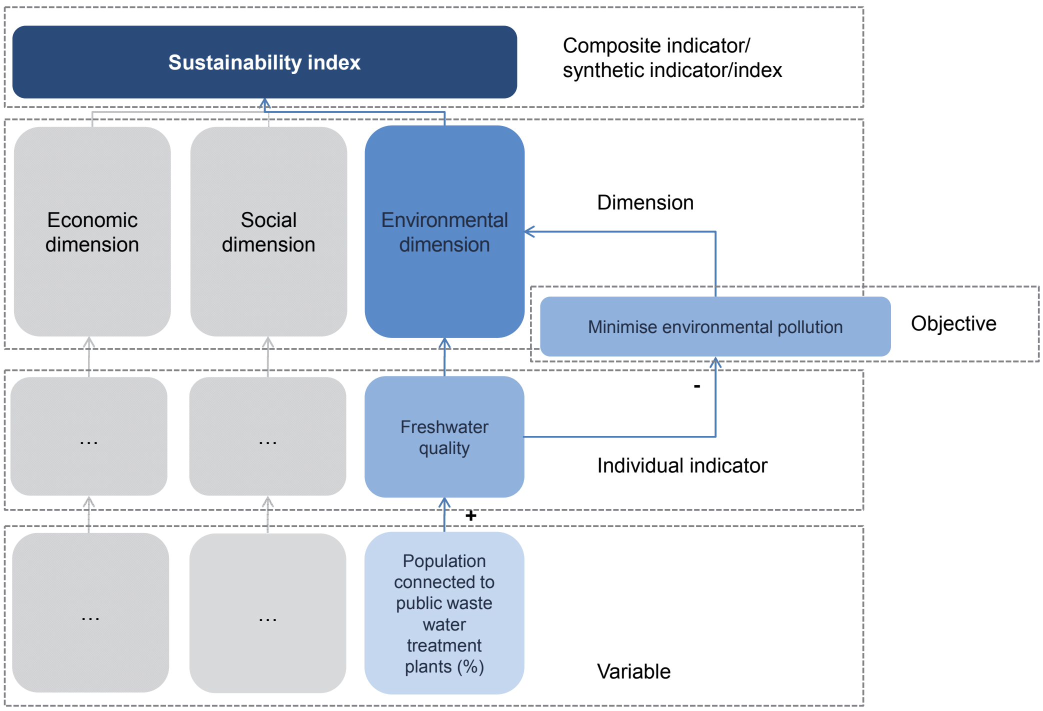
2 Composite indicators can be developed using data-driven approaches or theory-driven approaches (Niemeijer 2002). In the first case, existing data is exploited to best characterise the concept of interest, for instance the state of the environment. Data availability is hereby the central criterion for developing a composite indicator and data is provided for all individual indicators. In the second case, the theoretically best possible indicators are determined. The focus lies on the theoretical point of view, whereas data availability is only one of many aspects.
The theory-driven approach will hardly result in a composite indicator in the context of developing countries because of lacking data. Nevertheless, it might be worth the effort in order to develop a theoretically sound benchmark that offers guidance on which data would be needed in the ideal case. It could be a point of departure for future efforts to improve data collection, particularly in developing countries.

3 The terms 'composite indicator' and 'index' are used as synonyms below.

and variables used. In the example below, the composite indicator is a sustainability indicator. Each composite indicator consists of several *dimensions*. The dimension represents the highest hierarchical level of analysis. In the example, the sustainability indicator comprises the economic, social and environmental dimension.

The *objective* indicates the desired direction of change. The corresponding objective in the example is to minimise environmental pollution. An *individual indicator* represents the basis for evaluation with respect to a given objective. In the example below, freshwater quality contributes to minimising environmental pollution. A *variable* is a *"constructed measure stemming from a process that represents, at a given point in space and time, a shared perception of a real-world state of affairs consistent with a given individual indicator"* (OECD 2008, 51). For instance, the freshwater quality is better, the higher the share of the population that is connected to public waste water treatment plants. A variable is either directly the variable of interest or a proxy variable as an approximation of the variable of interest.

Figure 1: Different elements of a composite indicator



Source: Own elaboration based on OECD (2008, 51); OECD Environment Directorate (2008)

An indicator can be a single variable – such as annual rainfall deficit – or an aggregate, hence an indicator composed by several variables – such as air quality. From a statistical perspective, single variables and aggregates of several variables can be aggregated, as long as no variable is included as a single variable that is also part of an aggregate, and vice versa. If that were the case, the consequence would be a double-counting because the same factor was considered twice when calculating the index (OECD 2008).

Two related models are commonly used to classify environmental indicators into three to five categories. The *Pressure-State-Response (PSR) model*, developed by the OECD and the

European Environment Agency in the mid-1990s, is based on cause-effect relationships between human activities, changes in environmental conditions, and responses by society (Linster 2003). Human beings exert *pressure,* indirectly or directly, on the environment through their actions. These activities affect the quality of the environment and the quality and quantity of natural resources: the *state* of the environment. The *societal response* to these changes, individual or collective action or reaction, is visible in policies and in changing awareness and behaviour.[4]

The second model, the *Driving force-Pressure-State-Impact-Response (DPSIR)* model, is an extension of the pressure-state-response model.[5] The DPSIR framework examines three questions: (1) What is happening to the environment and why, (2) What are the consequences for the environment and humanity, and (3) What is being done and how effective is it (Pintér et al. 2009). *Drivers* such as demographical change, unsustainable production and consumption patterns and economic demand have impacts on the environment. These human interventions exert *pressures* on the state of the environment such as land-use change, emissions of pollutants and wastes, and resource extraction. Natural processes such as solar radiation, volcanoes and earthquakes also add to these environmental pressures. Such pressures cause changes in environmental *state* and trends including pollution, degradation and depletion of air, water, minerals and land. These changes have concurrent *impacts* on human and ecosystems. The analytical framework suggests *responses* to drivers, pressures and impacts.

2.1 Content-related challenges: Why is it challenging to measure the state of the environment?

The state of the environment is difficult to compare across countries because of the highly diverse initial conditions. Countries differ in environmental conditions, endowment with natural resources, and size. How can one compare the tropical rainforest in Brazil with the desert in Namibia? The difficulty is that environmental indicators can be very context-specific. For instance, a low level of biodiversity in a tropical rain forest has much more severe implications than the same low level of biodiversity in a dry savannah.

Although it may seem intuitively simple, it is conceptually challenging to measure the state of the environment. Two fundamentally important aspects are *what* should be measured and *how* it should be measured (Grunwald / Kopfmüller 2012), including which variables and individual indicators should be employed? Changes in the state of the environment are perceptible in the air, water, and land – the environmental media. Quite apart from technical questions and conceptual challenges, these decisions are also inadvertently related to subjective judgment and normative decisions because establishing thresholds or reference points is necessary to identifying critical values and because measuring the state of the environment in isolation is meaningless.

4 The Driving force-State-Response (DSR) is a variation of the PSR model. A *driving force* is a process or an activity that has a positive or negative impact on the environment. For instance, the CSD Indicators of Sustainable Development (please refer to Appendix A) use the DSR framework.

5 A nice illustration of the DPSIR model can be found in UNEP (2012, xx).

In the environmental realm, several specificities have to be taken into account:

- The selection of appropriate indicators is primarily defined by the concept one wants to measure; for instance, the state of the environment as such, or the state of the environment coupled with human well-being. The trophic state of a lake and the water quality of a lake, for example, are related concepts, but they measure different things.[6] The trophic state is an absolute scale that describes the biological condition of a water body. Trophic state is based upon biomass (total weight of living biological material) in a water body at a specific time and location. As a multidimensional concept, major physical, chemical, and biological expressions of trophic state need to be combined in order to reasonably measure the trophic conditions in a water body. Typically, chlorophyll, secchi disk depth (to measure the visibility depth), and total phosphorus are used to determine the trophic status of any lentic water body.[7] Water quality, in contrast, describes the condition of a water body in relation to human needs. Hence, judgments about the quality of the water depend on the intended use (e.g. for recreation, or fishing). Consequently, the trophic state is the appropriate indicator to measure the state of the environment, whereas water quality is the appropriate indicator to measure the environmental-human-wellbeing.

- Environmental indicators are often linked to an optimum value, rather than the maximum or minimum. For instance, the trophic status informs about an ecosystem becoming too rich or too poor in nutrients, relative to an ideal or normal state (Niemeijer 2002).

- Related to the previous point, determining a baseline value can be problematic due to the subjective judgment necessary to define which point of reference is acceptable (Niemeijer 2002).[8]

- The same aspect may be measurable in various ways. For instance, biodiversity can be measured by the stock of selected, particularly important species; by the number of listed endangered species; or by factors that threaten biodiversity (Grunwald / Kopfmüller 2012).

- Most indicators are expressed in relation to time, per capita or per GDP but very few indicators in relation to area (Kaly / Pratt / Mitchell 2004).[9]

- According to Niemeijer (2002) measuring the state of an ecosystem creates a dilemma: the ideal measurement is specific to the particular ecosystem, but indicators should not be ecosystem-specific. The best solution is thus to define indicators that are as uniform as possible across ecosystems and, if necessary, to define their measurement in a more ecosystem-specific manner (e.g., trophic status of lakes, soils, and streams expressed on a similar trophicity scale to create one indicator only).

---

6 The following summarises the main points presented in Pepper / Gerba / Brusseau (2006, 35–36).

7 *Lentic* refers to standing or relatively still water, as opposed to *lotic*, referring to flowing water.

8 This is certainly not a problem exclusive to environmental indicators.

9 Kaly / Pratt / Mitchell (2004) argue that, for most environmental indicators, density (per unit area over which effects can be attenuated) is the most important denominator.

– Scale is very important for environmental data because environmental problems can be global, regional, national, sub-national or municipal (UNEP 2012).[10] Hence, the relevant boundaries of an environmental process do not necessarily coincide with the administrative boundaries of countries.

– There is no generally accepted procedure for normalisation and weighting: Expert consultations bear the risk of subjective weightings, while statistically derived weights might be even less acceptable if politically insignificant variables are assigned high values (Böhringer / Jochem 2007).

– Finally, for all indices, the definition of the underlying concept is inseparably linked to its measurement: Depending on the definition, an indicator is (or is not) appropriate to measure the concept or to measure the progress toward a concept (Hák / Moldan / Dahl 2007). Furthermore, the definition itself of the underlying concept may be subject to debate.[11]

Despite considerable improvements in data quality, insufficient information on environmental data and monitoring remain at the global scale in the following areas: toxic chemical exposures, heavy metals, municipal and toxic waste management, nuclear safety, pesticide safety, wetlands loss, species loss, freshwater ecosystems health, water quality, recycling, agricultural soil quality and erosion, desertification, comprehensive greenhouse gas emission, and climate adaptation (Emerson et al. 2012, 15). Some issues are particularly relevant in developing countries. For instance, soil degradation is a challenge in rural areas with subsistence agriculture, whereas chemicals and waste pose a problem in densely populated urban areas – particularly for poor people. Other issues are universally applicable. For instance, freshwater and marine ecosystems as an ultimate place to sink pollutants indicate very sensitively the environmental impact of human activities (UNEP 2012). More comprehensive data coverage is thus desirable in order to draw a more complete picture in the future. This being said, data availability and data reliability are general concerns for all measurement efforts.

2.2 Technical challenges: How is an index or composite indicator constructed?

The construction of a composite indicator ideally follows a sequence of ten steps, from developing the theoretical framework to presenting and visualising the composite indicator (see Figure 2).[12] Each single step – as well as coherence in the whole process – is ex-

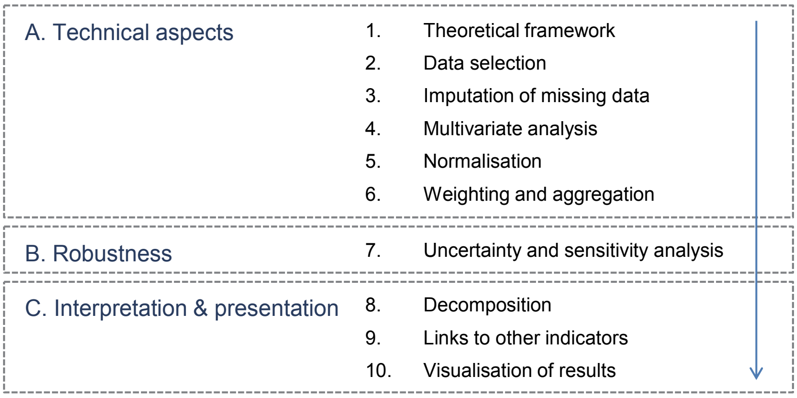
10 In the context of environmental indicators, according to Niemeijer (2002), *spatial aggregation* refers to the aggregation of values for the same indicator, or same set of indicators, over a number of ecosystems in order to obtain a single value per indicator for a particular region. *Conceptual aggregation* of environmental indicators refers either to the selection of key indicators that are considered to reflect the condition and trends of an ecosystem or to the construction of a composite indicator from several conceptually related indicators.

11 In fact, there is a lively debate about which indicators characterise good environmental conditions. Among other things, selecting appropriate indicators for water and soil quality is extremely difficult – not least due to the variety of variables to be considered (e.g., see the long list of elements for classifying the ecological status of water in Annex V of the European Water Framework Directive (EU (European Union) 2000).

12 The following presentation summarises the main points of the "Handbook on Constructing Composite Indicators. Methodology and User Guide" (OECD 2008).

tremely important. At each step, not only have the most appropriate methodological choices to be made, but all steps need to fit together. The first six steps deal with technical aspects of composing a synthetic indicator. Step Seven focuses on robustness and sensitivity analyses of the newly constructed indicator. Steps Eight to Ten centre on the interpretation of the composite indicator and the presentation of the results.[13]

Figure 2: Framework for index evaluation



Source: Own elaboration based on OECD (2008)

First, the *theoretical framework* is the basis of a properly constructed composite indicator. The multidimensional concept and its components are based on the theoretical framework. It is recommended that the indicators are selected and weighted such that their relative importance for composite indicators and for the respective dimension is adequately reflected, following the fitness-for-purpose principle.

Second, the strength and weakness of a composite indicator is strongly linked to the quality of the underlying variables. On the one hand, indicators and variables respectively must be chosen in accordance with the theoretical framework. On the other hand, even as guided by the theoretical framework, *data selection* may be quite subjective: The set of indicators may not be definitive while internationally comparable quantitative data may be scarce and then often substituted by qualitative data. Proxy measures need to be checked for accuracy. Variables require to be scaled by an appropriate size measure for objective comparison, regardless of, for example, the size of the country.[14] The type of variables – indicators for input, output, or process – must match the definition of the underlying concept.

Third, a necessary condition for calculating a composite indicator is that all *missing data* is imputed. Data from official international sources such as the World Bank, OECD, United Nations or the IMF stand out due to their reliable and publicly available data for many, if not

13 The first seven steps are part of an iterative process. If issues with conceptual or statistical coherence are detected at some point, previous decisions might need revision and subsequent additional multivariate analysis or uncertainty and sensitivity analysis. When presenting an index, however, the results of multivariate analysis are usually commented on *after* describing the weighting and aggregation method. It is this pattern we follow in the evaluation part.

14 Objectivity can refer to several things. A (social) indicator is objective if there is widespread agreement about the sign of what is being measured, if the characteristic can be measured with little measurement error or if it can be measured relatively independent of people's perceptions or opinions (Diener / Suh 1997).

all, countries. These data are prepared for cross-country comparisons, despite different definition or statistics at national level. Nevertheless, even these usually very comprehensive databases lack information for some countries, requiring the imputation of missing data.

Fourth, *multivariate analysis* is recommended when the interrelationships between items are to be studied – the underlying structure of the data. Thereby, it is assessed whether the dataset is suited and subsequent methodological choices such as weighting and aggregation are guided.

Fifth, the indicators, respectively variables, in a dataset are typically measured on different scales. Before any data aggregation, the different measurement units need to be *normalised* in order to make variables comparable. Common normalisation methods are e.g. ranking, min-max and distance-to-target.

Sixth, the next crucial step is to *weight* the indicators, respectively variables, and *aggregate* them appropriately in the composite indicator. Regardless of the weighting techniques, it is important to note that *"weights are essentially value judgements"* (OECD 2008, 31).

Seventh, the *uncertainty analysis* is used to distil how uncertainty in the input factors translates into the values of the composite indicators. The results of the robustness analysis are commonly reported as a ranking with the related uncertainty bounds. The *sensitivity analysis* is used to assess the contribution of the individual source of uncertainty to the variance in the output. The results are commonly shown as a sensitivity measure for each input source of uncertainty.

Eighth, *decomposing* the composite indicator into sub-components and individual indicators helps to understand the overall performance of, for instance, a given country. Country profiles and individual indicators can be presented using e.g. leaders and laggards, spider diagrams, and traffic light presentations. Ninth, the explanatory power of a composite indicator can be tested by *linking* the composite *to other variables* and measures. Cross-plots are frequently used to assess the overall correlation trend and possible outliers. Tenth, the *presentation* of the results for the composite indicator should help to communicate the story in a quick and accurate manner.

2.3 Country-related challenges: What are the measurement challenges in developing countries?

Measuring the state of the environment is already a challenge in developed countries and even more so in developing countries. Limited financial means, know-how and infrastructure to gather and process data represent additional constraints for reliable and available data for developing countries: *"Environment statistics frequently lack one or more of the standard attributes of high-quality statistics, namely, relevance, accuracy, timeliness, accessibility, interpretability and coherence. (...) environment statistics are ad hoc, widely dispersed and of varying degrees (...)."* (UN 2010, 3). But, internationally comparable data is a necessary condition to track environmental status and changes at the national, regional, and global level.[15] Availability and quality of data remain poor in a large number

15 The following summarises the main points of UNEP (2012, 216–224).

of countries. Data are often scattered across many public and private sources and are difficult to compare globally. Data availability is geographically unbalanced in almost all thematic areas. Data is less available in developing countries, with data fragmentation being even greater at sub-national levels. As regards *atmosphere*, climate data are scarce in developing countries. Data availability on greenhouse gases and other pollutants is more limited for countries that are not party to the convention in question. Many gaps exist in air quality data, including nitrates, particulate matter, and black carbon, particularly in developing countries. In terms of *land*, there are many deficiencies in the data available, including the extent of drylands and wetlands, land degradation, cover and use, urban area, deforestation, and carbon stocks. For *water*, data on groundwater (availability, quality, extraction, etc.) are more limited than data on surface waters; and there is less data on surface water quality than on surface water quantity. Limited data are available on groundwater contamination from nitrates and arsenic. With respect to *biodiversity*, monitoring is least extensive in tropical areas. Due to lacking data, it is difficult to link state of biodiversity and drivers of biodiversity loss. For *chemicals and waste*, in most developing countries, reliable data about waste generation, collection and management are lacking. In many developing countries, pollution hotspots are poorly documented. More data are needed on the generation of hazardous wastes and their treatment.

An additional challenge for cross-country environmental composite indicators is to select variables and indicators respectively that reflect the situation adequately in both developed and developing countries. As the level of development varies so strongly, in fact, indicators differ in importance, and different indicators may be suitable in each case. For instance, indoor air pollution due to cooking and heating with solid fuels on open fired or traditional stoves (WHO 2010) is a serious environmental problem with severe health effects in developing countries – but not in developed countries. Chemicals, released in extraction, production, consumption and waste disposal, are widely distributed in the ecosystem but mainly pose a problem in industrialised, urban areas.

3 Sources of information and their evaluation: What are the strengths and weaknesses of existing cross-country environmental indices in measuring the state of the environment?

It is a challenge to construct a composite indicator that is not only embedded in a convincing theoretical framework but that also deals with the many difficulties imposed by real-life circumstances in a reasonable way. Composite indicators face several significant challenges related to variable selection, missing data treatment, normalisation and aggregation formulae, and weighting methods. Environmental composite indicators face additional challenges because environmental data are *"notoriously spotty, unreliable, and uneven"* (Esty / Porter 2005, 393). Additionally, they need to adequately consider differences in initial environmental conditions in order to allow for cross-country comparison. Environmental composite indicators or indices aim at capturing the complexity of environmental systems. Six environmental indices are selected because they are relevant for measuring the environment, quantify the phenomenon, are accessible, are transparent in their construction and cover at least some developing countries.[16] The first evaluation criterion is to

16 Different from other indices published every year or every second year, most environmental indices are not regularly updated.

analyse to what extent they measure the state of the environment or what environmental features they cover. The second criterion is to assess the technical sophistication and soundness. The ten-steps-framework, as described in Section 2.2, is used to evaluate the technique of construction, the robustness of the index, as well as interpretation and presentation of results. The third criterion focuses on the extent to which developing countries, defined by income, are covered.

3.1 Ecosystem Wellbeing Index (EWI)

3.1.1 Framework

Background: The Ecosystem Wellbeing Index (EWI) aims at measuring the *"diversity and quality of the ecosystem and of the main pressures on them"* (Prescott-Allen 2001, 60) in 180 countries, for which data could be obtained on at least every second indicator. It is a composite of indicators for the dimensions land, water, air, species and genes, and resource use; using in total 51 variables (see Figure 3).[17]

Data selection: Indicators are selected on the basis of the criteria of representativeness, reliability, and feasibility.

Imputation: Missing or not applicable data are not imputed. The "insufficient data rule" is employed in order to prevent high scores in an indicator or an index merely because of a lack of data.

Normalisation: Performance scores measure the distance between the highest possible performance and the actual performance recorded by the indicator. The performance is classified into five bands (bad, poor, medium, fair, and good), with 100 and 0 indicating the best and the worst, respectively. At least one of the following criteria is used to set a band: estimated sustainable rate, estimated background rate, other threshold, international (or national) standard or target, expert opinion, derivation from a related indicator, or personal judgment.

Weighting and aggregation: Unweighted average, weighted average or veto is used to combine components (variables, indicator-subelements, indicators, or dimensions). Veto means that a lower score in one component overrides a higher score in another component. The weighting and aggregation method is chosen as deemed appropriate by subjective judgment.

Links to other indices: The rating of the EWI is compared to the rating of the ecological footprint (EF), without analysing any possible correlation between the two environmental indices.[18] The extent to which they are comparable, however, seems generally limited, given their underlying concept. The EF measures the pressure of consumption on the environment, whereas the EWI indicates environmental wellbeing.

---

17 The dimension resource use is only included when it does not cause a rise in the index, in order to prevent a high score for resource use from offsetting a poor state of the environment.

18 The EF measures the corresponding area of biologically productive land and aquatic ecosystems needed on a continuous basis to produce the resources used and to absorb all wastes discharged by a defined population at a specified material standard of living (Kitzes / Wackernagel 2009; Wackernagel / Rees 1996; Wackernagel et al. 2002); see also Appendix B).

Figure 3: The structure of the Ecosystem Wellbeing Index (EWI)

Name	Dimensions	Weight	Indicators	Weight	Indicators - Subelements	Weight	Variables	Weight
Ecosystem Wellbeing Index (EWI)	Land	1/5	Land diversity	*	Land modification and conversion	2/3	Converted land (% of total land)	1/3
							Natural land (% of total land)	1/3
							Change in native forest area (%)	1/3
					Land protection	1/3	Protected area (% of land and inland water area)	**
			Land quality	*		1	Degraded land (% of cultivated and modified land)	**
	Water	1/5	Inland water diversity	*	River conversion by dams	1	Dam capacity (% of total water supply)	OR
							River flow dammed for hydropower (% of dammable flow)	OR
			Inland water quality	*	Water quality of drainage basins****	1	Oxygen balance	*
							Nutrients	*
							Acidification	*
							Suspended solids	*
							Microbial pollution	*
							Arsenic and heavy metals	*
	Air	1/5	Global atmosphere index	*	Greenhouse gases	*	Carbon dioxide emissions/person	1
					Ozone depletion	*	Use of ozone depleting substances/person	1
			Local air quality index	*	City scores in each country	1	Sulphur dioxide	*
							Nitrogen dioxide	*
							Ground-level ozone	*
							Carbon monoxide	*
							Particulates	*
							Lead	*
	Species and genes	1/5	Wild diversity index	2/3	Wild plant species	1/2	Threatened plant species (% of total plant species)	**
					Wild animal species	1/2	Threatened animal species (% of total animal species)	**
			Domesticated diversity index	1/3		1/2	No. of not-at-risk breeds of a species/mio. head of species	**
						1/2	Threatened breeds of species/ not-at-risk breeds of species	**
	Resource use	1/5	Energy and materials index	1/2			Energy consumption/hectare of total area	*
							Energy consumption/person	*
			Resource sectors index	1/2	Agriculture	1/3	Agricultural productivity (***)	*
							Agricultural self-reliance (***)	*
					Fisheries	1/3	Fishing pressure (***)	*
							Fish and seafood self-reliance (***)	*
					Timber	1/3	Timber production (***)	1

* = whichever value is lower
** = specific weighting procedure applied (please refer to Prescott-Allen 2001)
*** = additional variables used for calculation (please refer to Prescott-Allen 2001)
**** = 17 basins.

Source: Own elaboration based on Prescott-Allen (2001)

Visualisation: The presentation of results is user-friendly and easy-to-read. The results of the index and every indicator used are individually presented by two graphics. A square graphic illustrates the performance criteria used to convert the indicator measurement to a score. A staircase graphic shows the distribution of the data, where the width of each step represents the proportion of the performance scale that falls within the band. In addition to the presentation of the results for the EWI, the Barometer of Sustainability displays where the Human Wellbeing Index (HWI) and the EWI intersect. The HWI measures human wellbeing as an average of five dimensions: health and population, wealth, knowledge and culture, community, and equity.[19] In particular, the Barometer of Sustainability is a very intuitive option to juxtapose the two indices Ecosystem Wellbeing and Human Wellbeing – visualising the targeted balance between ecosystem and human conditions.

3.1.2 Evaluation

Content: The EWI attempts to measure a highly relevant concept. It includes indicators for the atmosphere, lithosphere and hydrosphere as well as for the cross-cutting issues: chemicals and biodiversity.

Technique: Although it is conceptually very interesting, the EWI is methodologically weak. The main weaknesses are that scores are computed despite half of the data being missing and that the rules used for weighing and aggregation cause intransparent results. If the guidelines for constructing a composite indicator are used as a yardstick, the index does not qualify as a composite indicator. The decisions to not impute missing or non-applicable data and to calculate a score, whenever half of the data is available for a country, have serious consequences for index construction (see also 3.4.2). It means that an index score is computed with up to 50 percent of the missing indicators replaced by the average of the available indicators for that country. To further complicate the matter, the missing data may be information that is theoretically more relevant. Moreover, the mix of several aggregation methods (weighted average, unweighted average and veto) is confusing. The veto method – a lower score overriding a higher score – in particular reduces the transparency. The veto method disguises the actual contribution of each component, such as a variable or an indicator, to the aggregate. This method is used, firstly, when good performance is essential in both components of a pair; secondly, when inferior performance in one component outweighs superior performance in all others; and thirdly, to avoid counting the same feature more than once when it is represented by more than one component (Prescott-Allen 2001). Transparency is further lessened because some variables are only theoretically mentioned, but not actually used in the composite indicator. As a result, the construction of the EWI is not transparent, despite the effort to explicitly document all steps and decisions taken along the way.

Correlation analyses are useful to check whether indicators are randomly associated with the dimension or the overall index because a change in a randomly associated indicator will not lead to a change in the overall index and should therefore be avoided (OECD

19 Equity is only included when it does not raise the index, to prevent a high score on equity from offsetting poor human conditions.

2008). The cross-correlation analysis (Table 2) between the indicators and dimensions of the EWI reveals that the indicators are more correlated to their own dimension than to the other dimensions. All correlations are moderate to strong, significant and positive. The only exception is the correlation coefficient for the indicator local air quality which is not significant at the 5% level, implying a random association.

Table 2: Correlation structure in the Ecosystem Wellbeing Index (EWI) framework

EWI indicators	EWI dimensions				
	Land	Water	Air	Species and genes	Resource use
Land diversity	0.71***	0.22**			0.20**
Land quality	0.54***				
Water withdrawal	0.38***	0.63***	0.40***		0.45***
Water quality		0.97***			
Global atmosphere		0.39***	0.93***		0.77***
Local air quality	0.33*			0.28*	-0.45***
Wild diversity				0.93***	
Domesticated diversity				0.63***	
Energy materials		0.36***	0.79***		0.92***
Resources and sectors	0.32***	0.22**	0.31***		0.76***

Notes: Pearson correlation coefficients that are non-significant at the 95%-level are not reported.
***, **, and * denote significance at 0.1, 1, and 5 percent, respectively.

Source: Own elaboration

Country coverage: The ranking includes developing countries comprehensively, regardless of geographic area or income group. Yet, the broad country coverage is only made possible because of the limp requirement for missing data. Since missing data is not imputed but just replaced by average values, the extensive coverage comes at the cost of very imprecise scores.

3.2 Environmental Performance Index (EPI)

3.2.1 Framework

Background: The Environmental Performance Index (EPI) centres on two overarching objectives of environmental policy: environmental health, measuring environmental stresses to human health; and ecosystem vitality, measuring ecosystem health and natural resource management (Emerson et al. 2012). The EPI tracks outcome-oriented indicators on environmental issues. 132 countries are ranked on 22 variables, grouped into 10 indicators (see Figure 4).[20]

20 In 2012, the *Trend Environmental Performance Index* was introduced. It ranks countries on the change in environmental performance from 2000 to 2010 in order to visualise the improvement or decline in environmental performance of each country over time.

Figure 4: Structure of the Environmental Performance Index (EPI)

Name	Dimensions	Dimension weight	Indicators	Indicator weight	Variables	Variable weight
Environmental Performance Index (EPI)	Environ-mental health	30%	Environmental health	15.00%	Child mortality	15.00%
			Air *(effects on human health)*	7.50%	Particulate matter	3.75%
					Indoor air pollution	3.75%
			Water *(effects on human health)*	7.50%	Access to sanitation	3.75%
					Access to drinking water	3.75%
	Ecosystem vitality	70%	Air *(ecosystem effects)*	8.75%	SO_2 per capita	4.38%
					SO_2 per $ GDP	4.38%
			Water resources *(ecosystem effects)*	8.75%	Change in water quantity	8.75%
			Biodiversity and habitat	17.50%	Critical habitat protection	4.38%
					Biome protection	8.75%
					Marine protected areas	4.38%
			Agriculture	5.83%	Agricultural subsidies	3.89%
					Pesticide regulation	1.94%
			Forests	5.83%	Forest growing stock	1.94%
					Change in forest cover	1.94%
					Forest loss	1.94%
			Fisheries	5.83%	Coastal shelf fishing pressure	2.92%
					Fish stocks overexploited	2.92%
			Climate change and energy	17.50%	CO_2 per capita	6.13%
					CO_2 per $ GDP	6.13%
					CO_2 per KWH	2.63%
					Renewable electricity	2.63%

Source: Own elaboration based on Emerson et al. (2012)

Data selection: For data selection, strict criteria (relevance, performance orientation, established scientific methodology, data quality, time series availability, completeness) are used to assess whether a dataset is adequate to measure performance on pressing environmental concerns.

Imputation: When values are missing in the interior of a time series, values are imputed based on the closest available data points. When values are missing at the beginning or end of a time series, values are extrapolated using the closest year of available data.

Normalisation: The proximity-to-target method quantifies and benchmarks each country's performance on any indicator. For each country and each indicator, a proximity-to-target score is calculated, reflecting the gap between a country's current result and the target. A score of 100 is equivalent to achieving or exceeding the target on a 0-to-100 scale. The targets are established using input from treaties or other internationally agreed-upon goals, standards set by international organisations, leading national regulatory requirements, expert judgment, and ranges of values observed in the data. The ranking indicates *"which countries are doing best in terms of reaching common environmental targets."* (Moldan / Janoušková / Hák 2012, 10).

Weighting and aggregation: The dimension environmental health is the arithmetic average of the indicators environmental health, water (effects on human health), and air pollution (effects on human health). The dimension ecosystem vitality is the arithmetic average of the indicators air pollution (ecosystem effects), water resources (ecosystem effects), biodiversity and habitat, forests, fisheries, agriculture and climate change. In the last edition from 2012, the environmental health objective contributes 30% and the ecosystem vitality adds 70% to the overall score. The different relative weights aim at achieving a balance between the contribution of the two dimensions to the index (Emerson et al. 2012), but the weights also reflect the number of indicators included in each dimension (Saisana / Saltelli 2012). When aggregating variables, a variable is included if assessed as relevant. Otherwise the other variables in the same indicator receive more weight; examples are forest cover in desert countries or marine fisheries in landlocked countries (Emerson et al. 2012).

Multivariate analysis: The results of the principal component analysis (PCA) suggest that employing an arithmetic average is statistically justified for the dimension environmental health, but questionable for the dimension ecosystem vitality (Saisana / Saltelli 2012).[21]

Uncertainty and sensitivity: Testing how robust the results – the country ranking – are to methodological assumptions, the overall classification was assessed as highly confident (Saisana / Saltelli 2010) in the 2010 EPI. However, no uncertainty and sensitivity analysis was performed with the 2012 EPI which is the latest edition.

Visualisation: The country classification is visualised in a ranking. Changes in the two dimensions over time, as well as their trends, are illustrated.

3.2.2 Evaluation

Content: The index covers several environmental spheres, general aspects such as biodiversity as well as the link between humans and environment.

The indicator environmental health, measuring the impact of environmental conditions on human health, is only based on the variable child mortality. The informative content of this variable is, however, rather limited. Typically, the under-five mortality rate shows high values in developing countries with tropical climate conditions that lack the health infrastructure to deal with diseases prone to tropical areas; in more devel-

21 Note that the 2000 to 2010 dataset was used for the PCA.

oped countries, respectively countries with other climatic conditions, child mortality may be related to environmental pollution (Niemeijer 2002). Child mortality does not reflect serious health consequences caused by pollution either among children alive or among adolescents or adults in general, as the variable documents the extreme event of death. In addition, the variables access to drinking water and sanitation are correlated with child mortality as they represent important drivers of childhood diseases such as diarrhoea which causes premature deaths. To sum up, it is questionable whether child mortality is a suitable measure of the impact of the environment on human health – namely the effect of environmental pollution on human health.[22] On a similar note, for the sake of clarity an indicator should not have the same name as a dimension.

Variables used in the dimension ecosystem vitality may be surprising: examples might be agricultural subsidies and renewable electricity. Yet, when evaluating single indicators, it is important to keep in mind that the index focuses on environmental issues for which governments can be held accountable (Saisana / Saltelli 2012). Hence, variables and indicators are used to reflect the promotion of ecosystem vitality and sound natural resource management, not ecosystem vitality as such. For this reason, the index includes indicators that affect this objective positively (renewable electricity) or negatively (agricultural subsidies).

The index covers several environmental spheres, general aspects such as biodiversity, as well as the link between humans and environment. Due to significant gaps in environmental data and monitoring, limited country coverage, and lack of time series, some issues relevant to policy and some scientifically important ones could not be included (Emerson et al. 2012).

Technique: Its statistical and conceptual foundation is generally convincing, with excellent data coverage (Saisana / Saltelli 2012).

A detailed analysis of the correlation structure within and across the EPI indicators shows that the variables are more correlated to their own indicator than to any other indicator (Table 3). All correlations within one indicator are significant and positive. From a statistical point, these results imply that, first, the variables do not need to be reallocated to different indicators and, second, no trade-offs are present because all correlation coefficients are significant and positive (Saisana / Philippas 2012). The two indicators environmental health and water resources are based on only one variable each; hence, the variable is perfectly correlated ($r = 1$) with the indicator.

22 Emerson et al. (2012) are aware of these limitations and suggest Environmental Burden of Disease or child mortality by cause as more useful indicators – but they cannot be used because both indicators suffer from poor data availability, particularly in terms of time series data.

Table 3: Coherence test in the Environmental Performance Index (EPI) framework

		EPI indicators									
EPI indicators	**EPI variables**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**
I. Environmental health	Child mortality	1.00	0.75***	0.87***	-0.19*	-0.17	0.10	-0.05	0.28**	-0.15	-0.56***
II. Air ***(effects on human health)***	Particulate matter	0.38***	0.63***	0.36***	-0.05	0.26**	0.23*	-0.00	-0.09	0.06	-0.09
	Indoor air pollution	0.74***	0.93***	0.79***	-0.10	-0.20*	0.09	-0.07	0.24**	-0.16	-0.64***
III. Water ***(effects on human health)***	Access to sanitation	0.83***	0.78***	0.97***	-0.14	-0.20*	-0.00	-0.10	0.31***	-0.25**	-0.56***
	Access to drinking water	0.86***	0.73***	0.96***	-0.16	-0.11	0.18*	-0.07	0.31***	-0.27**	-0.52***
IV. Air ***(ecosystem effects)***	SO_2 per capita	-0.51***	-0.45***	-0.49***	0.90***	0.28***	-0.00	0.06	-0.30***	0.11	0.69***
	SO_2 per $ GDP	0.20*	0.27**	0.25**	0.89***	0.34***	0.27**	-0.03	-0.10	-0.05	0.18*
V. Water resources ***(ecosystem effects)***	Change in water quantity	-0.17	-0.08	-0.16	0.35***	1.00	0.35***	-0.05	-0.16	0.02	0.33***
VI. Biodiversity and habitat	Critical habitat protection	0.20	0.25	0.25	-0.17	-0.13	0.69***	0.05	-0.17	-0.08	-0.36**
	Biome protection	-0.02	0.09	0.01	0.17*	0.40***	0.88***	-0.03	-0.26**	-0.02	0.11
	Marine protected areas	0.37***	0.27**	0.31**	-0.20*	0.12	0.49***	-0.01	0.05	-0.16	-0.16
VII. Agriculture	Agricultural subsidies	-0.49***	-0.42***	-0.47***	0.07	-0.06	-0.26**	0.79***	-0.32***	0.25*	0.30***
	Pesticide regulation	0.53***	0.41***	0.44***	-0.02	0.03	0.14	0.37***	0.11	-0.15	-0.22*
VIII. Forests	Forest growing stock	0.13	0.11	0.16	-0.18	0.02	-0.14	-0.22*	0.80***	0.05	-0.21*
	Change in forest cover	0.54***	0.40***	0.55***	-0.23**	-0.25**	-0.19*	-0.13	0.81***	-0.29**	-0.43***
	Forest loss	-0.24**	-0.31***	-0.21*	0.06	0.04	-0.14	-0.15	0.47***	0.14	0.21*
IX. Fisheries	Coastal shelf fishing pressure	-0.03	0.03	-0.14	-0.01	0.10	0.02	-0.03	0.02	0.66***	0.06
	Fish stocks overexploited	-0.21*	-0.19	-0.22*	0.07	-0.16	-0.20*	0.08	-0.14	0.59***	0.01
X. Climate change and energy	CO_2 per capita	-0.70***	-0.72***	-0.74***	0.34***	0.16	-0.14	0.19*	-0.32***	0.15	0.88***
	CO_2 per $ GDP	-0.26**	-0.26**	-0.25**	0.57***	0.33***	0.18*	-0.02	-0.23**	-0.07	0.85***
	CO_2 per KWH	-0.10	-0.05	-0.03	0.28***	0.33***	0.07	-0.13	-0.04	-0.18	0.57***
	Renewable electricity	-0.30***	-0.29***	-0.24**	0.33***	0.43***	0.07	-0.02	-0.21*	-0.09	0.75***

Source: Own elaboration

A cross-correlation analysis reveals that the three indicators of environmental health are more correlated to their own dimension environmental health than to the other dimension ecosystem vitality (Table 4). All correlations within this dimension are significant and positive.

Table 4: Correlation structure in the Environmental Performance Index (EPI) framework

EPI indicators	EPI dimensions	
	Environmental health	Ecosystem vitality
Environmental health	0.96***	-0.25**
Air ***(effects on human health)***	0.87***	-0.21*
Water ***(effects on human health)***	0.95***	-0.25**
Air ***(ecosystem effects)***		0.59***
Water resources ***(ecosystem effects)***		0.63***
Biodiversity and habitat		0.68***
Agriculture		
Forests	0.28**	-0.28**
Fisheries		
Climate change and energy	-0.59***	0.65***

Notes: Pearson correlation coefficients that are non-significant at the 95%-level are not reported.
***, **, and * denote significance at 0.1, 1, and 5 percent, respectively.

Source: Own elaboration

The results for the second dimension are more heterogeneous. Again, all indicators are more correlated to their own dimension ecosystem vitality than to the other dimension. However, the indicator forests is only weakly correlated with its own dimension. The negative coefficient suggests the presence of a trade-off between forests and ecosystem vitality. The correlation coefficients for the indicators agriculture and fisheries are not significant at the 5% level, implying practically random correlations. These random associations do not mean that these indicators measure redundant environmental issues, but that, if a country improves with respect to any of these two indicators, this improvement will not translate into a better position in the EPI (Saisana / Saltelli 2010). Following parsimony principles – to identify relevant indicators – would suggest the exclusion of non-influential indicators (Gall 2007). Yet, this may not be advisable because the indicator may be relevant from a theoretical perspective – and its exclusion may face strong resistance by experts (Saisana / Saltelli 2010).

According to Saisana and Saltelli (2012), as also shown above, the 2012 EPI is statistically coherent and balanced with respect to the two main dimensions, and within the dimension environmental health. The negative association between the two dimensions environmental health and ecosystem vitality warns against linear aggregation into a single number; other aggregation strategies such as the geometric average are suggested. The country classification is not dominated by any of the two objectives, although the dimension ecosystem vitality seems to be more important. The results of the principal component analysis suggest that employing an arithmetic average is statistically justified for the dimension environmental health, but questionable for the dimension ecosystem vitality. Using an arithmetic average to combine information in the dimension ecosystem vitality seems problematic because of negative and random associations between its policy categories.

Country coverage: Developing countries are not as extensively covered as in other indices, due to strict data requirements. Less than two-thirds of developing countries are included in the country ranking. Only every second country is included on the African continent, none in Oceania. Upper-middle income countries are relatively well covered, while only every second lower-middle income country is included in the ranking. The relatively low coverage of developing countries is caused by high data standards that improve the quality of the index and are recommended from a statistical perspective. However, as data are often lacking or of lower quality in developing countries, these strict requirements imply that many developing countries are not represented in the index.

3.3 Environmental Sustainability Index (ESI)

3.3.1 Framework

Background: The predecessor of the EPI, the Environmental Sustainability Index (ESI) (Esty et al. 2005) launched in 2000, was one of the first attempts to create a composite indicator instead of reporting data series for individual indicators (Niemeijer 2002) and was further developed and published till 2005. The index reflects a country's present environmental quality along with its capacity to maintain and its scope to improve conditions in the future (Hák 2007). 146 countries are ranked on 21 indicators of environmental sustainability, grouped into five components (environmental systems, reducing environmental stresses, reducing human vulnerability, social and institutional capacity, and global stewardship; see Figure 5).

Data selection: Country size, variable coverage and indicator coverage are used as inclusion criteria for countries, not indicators or variables.

Imputation: A two-step procedure is employed to transform the variables (Esty et al. 2005). Before imputing missing variables, a variable with a skewness value greater than two is transformed by logarithmic or power transformation. After the imputation, all variables are transformed back to their original scale, except extremely skewed variables whose skewness value is at least four. Markov Chain Monte Carlo simulation is employed to substitute missing data with plausible quasi-random draws from their conditional distribution given the observed data. Some variables, however, are not imputed because they depend strongly on conditions not captured by the index or ancillary variables. The missing values are replaced by the average of all values in each cell in the data matrix. After imputation, the tails of the variable distributions are trimmed in order to avoid a few extreme values dominating the aggregation algorithm.

Normalisation: All variables are converted to z-scores which preserve the relative distance between countries' values. Once the mean has been subtracted from the observation, the result is divided by the variable's standard deviation.

Weighting and aggregation: At the highest level of aggregation, the index is the equally weighted sum of 21 indicators. Each of the five core components is calculated by taking the average of the underlying variables. At the lowest level of aggregation, each indicator is also the equally weighted sum of the 2 to 12 underlying variables (Esty et al. 2005, 64).

Figure 5: Structure of the Environmental Sustainability Index (ESI)

Name	Dimensions	No.	Indicators	No.	Variables	No.
Environmental Sustainability Index (ESI)	Environmental systems	1	Air quality	1	Urban population weighted NO_2 concentration	1
					Urban population weighted SO_2 concentration	2
					Urban population weighted TSP concentration	3
					Indoor air pollution from solid fuel use	4
			Water quantity	2	Freshwater availability per capita	5
					Internal groundwater availability per capita	6
			Water quality	3	Dissolved oxygen concentration	7
					Electrical conductivity	8
					Phosphorus concentration	9
					Suspended solids	10
			Biodiversity	4	% of country's territory in threatened ecoregions	11
					Threatened bird species as % of known breeding bird species in each country	12
					Threatened mammal species as % of known mammal species in each country	13
					Threatened amphibian species as % of known amphibian species in each country	14
					National Biodiversity Index	15
			Land	5	% of total land area (including inland waters) having very low anthropogenic impact	16
					% of total land area (including inland waters) having very high anthropogenic impact	17
	Reducing environmental stresses	2	Reducing air pollution	6	Anthropogenic NO_x emissions per populated land area	18
					Anthropogenic SO_2 emissions per populated land area	19
					Anthropogenic VOC emissions per populated land area	20
					Coal consumption per populated land area	21
					Vehicles in use per populated land area	22
			Reducing water stress	7	Industrial organic water pollutant (BOD) emissions per available freshwater	23
					Fertilizer consumption per hectare of arable land	24
					Pesticide consumption per hectare of arable land	25
					% of country under severe water stress	26
			Reducing ecosystem stress	8	Annual average forest cover change rate 1990–2000	27
					Acidification exceedance from anthropogenic sulphur deposition	28
			Reducing waste and consumption pressures	9	Ecological Footprint per capita	29
					Waste recycling rates	30
					Generation of hazardous waste	31
			Reducing population pressure	10	% change in projected population 2004–2050	32
					Total fertility rate	33

Figure 5 (cont.): Structure of the Environmental Sustainability Index (ESI)

Name	Dimensions	No.	Indicators	No.	Variables	No.
Environmental Sustainability Index (ESI)	Reducing environmental stresses	2	Natural resource management	11	Productivity overfishing	34
					Salinized area due to irrigation as % of total arable land	35
					% of total forest area that is certified for sustainable management	36
					World Economic Forum Survey on subsidies	37
					Agricultural subsidies	38
	Reducing human vulnerability	3	Basic human sustenance	12	% of undernourished in total population	39
					% of population with access to improved drinking water source	40
			Environmental health	13	Death rate from intestinal infectious diseases	41
					Child death rate from respiratory diseases	42
					Children under five mortality rate per 1,000 live births	43
			Exposure to natural disasters	14	Average number of deaths per million inhabitants from floods, tropical cyclones, and droughts	44
					Environmental Hazard Exposure Index	45
	Social and institutional capacity	4	Environmental governance	15	% of total land area under protected status	46
					Ratio of gasoline price to world average	47
					% of variables missing from the CGSDI "Rio to Joburg Dashboard"	48
					Knowledge creation in environmental science, technology, and policy	49
					IUCN member organisations per million population	50
					Local Agenda 21 initiatives per million people	51
					Corruption measure	52
					Rule of law	53
					Civil and political liberties	54
					World Economic Forum Survey on environmental governance	55
					Government effectiveness	56
					Democracy measure	57
			Eco-efficiency	16	Energy efficiency	58
					Hydropower and renewable energy production as % of total energy consumption	59
			Private sector responsiveness	17	Dow Jones Sustainability Group Index (DJSGI)	60
					Average Innovest EcoValue rating of firms headquarted in a country	61
					Number of ISO 14001 certified companies per billion $ GDP (PPP)	62
					World Economic Forum Survey on private sector environmental innovation	63
					Participation in the Responsible Care Program of the Chemical Manufacturer's Association	64

Figure 5 (cont.): Structure of the Environmental Sustainability Index (ESI)

Name	Dimensions	No.	Indicators	No.	Variables	No.
Environmental Sustainability Index (ESI)	Social and institutional capacity	4	Science and technology	18	Innovation Index	65
					Digital Access Index	66
					Female primary education completion rate	67
					Gross tertiary enrollment rate	68
					Number of researchers per million inhabitants	69
	Global stewardship	5	Participation in international collaborative efforts	19	Number of memberships in environmental intergovernmental organisations	70
					Contribution to international and bilateral funding of environmental projects and development aid	71
					Participation in international environmental agreements	72
			Greenhouse gas emissions	20	Carbon emissions per million US $ GDP	73
					Carbon emissions per capita	74
			Reducing transboundary environmental pressures	21	SO_2 exports	75
					Import of polluting goods and raw materials as % of total imports of goods and services	76

* The ESI score is the average of the 22 indicators, NOT the five components. Each indicator is calculated by taking the average of the underlying variables. The five core components are calculated by taking the average of the associated indicators.

Source: Own elaboration based on Esty et al. (2005)

Multivariate analysis: Principal Component Analysis is used to examine potential links between the indicators used for constructing the index (Esty et al. 2005). The results corroborate that the index is a multidimensional index, that some indicators are more closely related than others, and that none of the indicators is redundant. Exhaustive stepwise linear regression analysis is used to determine those variables that are most influential in a variable set; 12 variables are identified. Cluster analysis is used to identify groups of relevant peer countries; identifying seven clusters.

Uncertainty and sensitivity: The sensitivity of the index is analysed in terms of the main methodological sources of uncertainty: imputation, weighting scheme (equal weighting vs. experts opinion weighting), aggregation level (indicators vs. components), and aggregation method (linear vs. non-compensatory) (Saisana / Nardo / Saltelli 2005). The results show that the impact of the four inputs of uncertainty is small to modest. Imputation of missing values changes a country's rank by ten positions on average; the weighting scheme has an average impact of eight ranks and matters mostly for mid-performing countries; the aggregation level changes a country's rank by eight positions; and the aggregation method has an average impact of five ranks. Other sources of uncertainty cannot be measured or are insignificant: The measurement error of the variables is unknown. The inclusion criteria, transformation, winsorisation and normalisation have a negligible effect on changes in the country ranks.

Links to other indices: The ESI is inversely correlated with the ecological footprint index. A weak relationship, but no significant trend between the ESI and the Environmental Vulnerability Index is found. A principal component analysis was used to create a single index out of six available indicators on Millennium Development Goal (MDG) 7. The result is a strong positive correlation between the ESI and the MDG index; however, it was only possible to calculate the MDG index for a limited number of countries.

Visualisation: The results are comprehensively presented. In addition to maps and tables informing about scores and rankings, the results are differentiated in country profiles, variable profiles, as well as component and indicator scores. The scores for five small states are presented separately.

3.3.2 Evaluation

Content-related aspects: Similar to its successor, the ESI covered many environmental spheres. In addition to aspects of the atmosphere, lithosphere and hydrosphere, general environmental factors as well as environmental health are included.

Technique: The aim of the predecessor ESI was to benchmark the ability of countries to protect their environment in the future (Esty et al. 2005) in order to base environmental decision-making on a firm analytic foundation with the help of environmental indicators (Hák 2007). It covered developing countries extensively, but excluded countries with less than 100,000 inhabitants or with a land area of under 5,000 square kilometres due to the "fundamentally different" environmental challenges of small countries (Esty et al. 2005, 381). The sophisticated technical and methodological content was very comprehensively documented and well-reasoned. Yet, the wide range of elements related to environmental sustainability made the aggregation in a single index problematic (Niemeijer 2002) and limited its utility for policymakers (Emerson et al. 2012).

Analysing the cross-correlations between ESI indicators and ESI dimensions (Table 6), the results show that most indicators are more strongly correlated with their own dimension than with other dimensions. With one exception, correlations are significant and positive. Still, several other correlation coefficients are noteworthy. The indicator air quality is only weakly correlated with the dimension environmental systems, but strongly correlated with the dimension reducing human vulnerability. In a similar vein, the indicator reducing population pressure is uncorrelated with its dimension, but strongly correlated with reducing human vulnerability. Similarly, the indicator eco-efficiency is weakly correlated with its own dimension, but strongly correlated with the dimension global stewardship. The indicator participation in international efforts is moderately correlated with global stewardship, but strongly correlated with the dimension social and institutional capacity. From a statistical perspective, these indicators may need to be reallocated to another dimension.

Indeed, the index suffered from some conceptual problems. For instance, the index was biased in favour of developed countries at the expense of developing countries, by including too many measures of capacity and by favouring technological innovations (Niemeijer 2002; Hák 2007). The distinction between a poor natural state of the environment, in which the natural endowments of a country may be severely restricted, and a deteriorating state of the environment, in which human action may reduce natural endowments was criticised as insufficient (Niemeijer 2002). The index loosely uses driving force, pressure, state, impact and response indicators, averaging across the individual indicators without applying any weights. The equal weighting of the indicators seemed arbitrary and inappropriate (Hák 2007). The relative contribution of an individual variable, the variable

Table 5: Correlation structure in the Environmental Sustainability Index (ESI) framework					
ESI indicators	**ESI dimensions**				
	Environmental systems	**Reducing environmental stresses**	**Reducing human vulnerability**	**Social and institutional capacity**	**Global stewardship**
Air quality	0.17*		0.56***	0.19*	-0.40***
Water quantity	0.80***	0.36***			
Water quality	0.65***		0.32***	0.51***	
Biodiversity	0.46***	0.21*	-0.22**	-0.17*	
Land	0.65***	0.43***	-0.33***	-0.34***	
Reducing air pollution	0.26**	0.73***	-0.60***	-0.58***	0.29***
Reducing water stress	0.42***	0.66***	-0.49***	-0.38***	0.29***
Reducing ecosystem stress	0.20*	0.33***		-0.19*	-0.22**
Reducing waste and consumption pressures	-0.19*	0.36***	-0.43***	-0.28***	0.30***
Reducing population pressure			0.74***	0.52***	-0.38***
Natural resource management	0.19*	0.61***	-0.38***	-0.53***	
Basic human sustenance		-0.40***	0.88***	0.60***	-0.31***
Environmental health		-0.28***	0.84***	0.69***	
Exposure to natural disasters	0.27**		0.49***		
Environmental governance		-0.47***	0.65***	0.92***	
Eco-efficiency	0.18*	0.21*	-0.32***	0.24**	0.63***
Private sector responsiveness		-0.52***	0.64***	0.89***	
Science and technology		-0.50***	0.76***	0.79***	-0.21*
Participation in international collaborative efforts		-0.35***	0.35***	0.67***	0.45***
Greenhouse gas emissions			-0.50***		0.78***
Reducing transboundary environmental pressures			-0.30***	-0.18*	0.71***

Notes: Pearson correlation coefficients that are non-significant at the 95%-level are not reported.
***, **, and * denote significance at 0.1, 1, and 5 percent, respectively.

Source: Own elaboration

weight, reduces in proportion to the number of variables in a given indicator – in the index 76 variables are unevenly distributed among 21 indicators. Implicit weights for variables range from 1/42 to 1/252 because each indicator is constructed of 2 to 12 underlying variables (Esty et al. 2005, 93). The index is built as a relative index in which countries are scored relative to all other countries in the sample. The advantage is that, as no baseline values need to be defined, the potential for disputes is reduced and the general acceptability is increased – but the assessment of progress towards sustainability is difficult because a country's score depends on the scores of other countries (Niemeijer 2002).[23] In addition, ranking relative to other countries does not reflect whether the current environmental state occurs within sustainable limits (Kaly /Pratt / Mitchell 2004).

Country coverage: The last edition covered many developing countries; most comprehensively the European and Asian continent. Only one developing country located in Oceania was included, certainly because small countries were excluded per se. In terms of income, low income countries were the best-covered group.

3.4 Environmental Vulnerability Index (EVI)

3.4.1 Framework

Background: The Environmental Vulnerability Index (EVI) estimates country profiles in terms of the resilience and vulnerability of environmental systems and resources to future natural and anthropogenic shocks (Kaly /Pratt / Mitchell 2004).[24] The index aims to reflect the extent to which the natural environment in a country is prone to damage and degradation (Kaly /Pratt / Mitchell 2004); not a simple undertaking because ecosystem integrity requires a set of indicators that takes account of different spatial and temporal scales and hierarchical levels of ecosystems (Pratt / Kaly / Mitchell 2004).[25] The index is based on 50 indicators, characterising the risks to and resilience of natural systems. Hazards, resistance and damage are three distinct aspects of vulnerability. Hazards relates to the probability of hazards, resistance relates to the resistance to damage, whereas damages refer to the acquired vulnerability from past damage. The three are linked in that resistance and damage refer to the ability of the environment to resist the effects of hazards. 32 hazard indicators mirror the risk of hazard occurrences, as they measure the frequency and intensity of hazardous events (see Figure 6). 8 resistance indicators reflect the inherent resistance to damage by measuring the inherent country characteristics to cope with natural and anthropogenic hazards. 10 damage indicators measure the acquired vulnerability as a result of past damage through loss of ecological integrity or increasing degradation of ecosystems.

Data selection: Indicators are selected to ensure spread of information across different elements and a cross-section of the ecological processes, reflecting different elements of ecological processes such as weather and climate, geology, geography, ecosystem resources and services, and human populations. In addition, sub-indices are generated for climate change, exposure to natural disasters, biodiversity, desertification, water, agriculture and fisheries, and human environmental health.

Imputation: Missing or not-applicable data have not been imputed (see also 3.4.2).

---

23 When scoring is done relative to other spatial units, natural environmental differences between different regions and different ecosystems need to be corrected for, to avoid bias and misinterpretation, using land cover and land use data (Niemeijer 2002).

24 Environmental vulnerability refers to the integrity of the ecosystem and its exposure to natural and anthropogenic hazards.

25 The natural environment is defined as *"those biophysical systems that can be sustained without human support"*, excluding the built environment like cities and farms (Kaly / Pratt / Mitchel 2004, 35). Built-up land – infrastructure for housing, transportation, and industrial production – is the most poorly documented of all land use types; estimates for global total built-up land amount to 0.2 billion hectares, corresponding to approximately 2.27% of global land area (Kitzes et al. 2007).

Figure 6: Structure of the Environmental Vulnerability Index (EVI)

Name	Dimensions	No.	Indicators	No.	Variables	No.
Environmental Vulnerability Index (EVI)	Damage*	1	Ecosystem imbalance	1	Change in trophic level	1
			Introductions	2	No. of introduced species	2
			Endangered species	3	No. of endangered and vulnerable species	3
			Extinctions	4	No. of species known to have become extinct since 1900	4
			Natural vegetation cover remaining	5	% of natural and regrowth vegetation cover remaining	5
			Habitat fragmentation	6	Total length of all roads in a country	6
			Degradation	7	% of land area (very) severely degraded	7
			Human population density	8	Total human population density	8
			Coastal settlements	9	Density of people living in coastal settlements	9
			Human conflicts	10	No. of conflict years per decade (past 50 yrs)	10
	Hazards*	2	High Winds	11	Annual excess wind	11
			Dry periods	12	Annual rainfall deficit	12
			Wet periods	13	Annual excess rainfall	13
			Hot periods	14	Annual excess heat	14
			Cold periods	15	Annual heat deficit	15
			Sea temperatures	16	Annual deviation in sea surface temperatures	16
			Volcanoes	17	Cumulative volcano risk	17
			Earthquakes	18	Cumulative earthquake energy	18
			Tsunamis	19	No. of tsunamis or storms surges	19
			Slides	20	No. of slides	20
			Environmental openness	21	Total freight imports per year per land area	21
			Rate of loss of natural vegetation cover	22	Net % change in natural vegetation cover	22
			Terrestrial reserves	23	% of terrestrial land area legally set aside as no-take reserves	23
			Marine reserves	24	% of continental shelf designated as marine protected areas	24
			Intensive farming	25	Annual tonnage of intensively farmed animal products	25
			Fertilizers	26	Annual intensity of fertilizer use over total land area	26
			Pesticides	27	Annual pesticides used over total land area	27
			Biotechnology	28	No. of deliberate field trials of GMOs since 1986	28
			Productivity overfishing	29	Ratio of productivity	29
			Fishing effort	30	Annual no. of fishers per km of coastline	30
			Renewable water	31	Annual water usage as % of renewable water resources	31
			Sulphur dioxide emissions	32	Annual SO_2 emissions	32
			Waste production	33	Annual net amount of generated and imported waste	33

Figure 6 (cont.): Structure of the Environmental Vulnerability Index (EVI)						
Name	**Dimensions**	**No.**	**Indicators**	**No.**	**Variables**	**No.**
Environmental Vulnerability Index (EVI)	Hazards*	2	Waste treatment	34	Annual % of waste effectively managed and treated	34
			Industry	35	Annual use of electricity for industry	35
			Spills	36	Total no. of spills of oil and hazardous substances	36
			Mining	37	Annual mining production	37
			Sanitation	38	Density of population without access to safe sanitation	38
			Vehicles	39	No. of vehicles	39
			Human population growth	40	Annual human population growth	40
			Tourists	41	Annual no. of international tourists	41
			Environmental agreements	42	No. of environmental treaties in force	42
	Resistance*	3	Land area	43	Total land area	43
			Country dispersion	44	Ratio of length of borders to total land area	44
			Geographic isolation	45	Distance to nearest continent	45
			Relief	46	Altitude range	46
			Lowlands	47	Percentage of land area above sea level (max. 50m)	47
			Shared borders	48	No. of land and sea borders shared with other countries	48
			Migratory species	49	No. of known species migrating outside the territorial area	49
			Endemic species	50	No. of known endemic species	50
Note: Three aspects of vulnerability (damage, hazards, resistance) do NOT build a composite indicator, but a composite indicator is built from simple average across all individual indicators. * = average over last 5 years.						
Source: Own elaboration based on Kaly / Pratt / Mitchell (2004)						

Normalisation: The scale ranges between 1 and 7 where 1 indicates low vulnerability or high resilience[26] and 7 indicates high vulnerability or low resilience (Kaly / Pratt / Mitchell 2004). Countries are categorised into five vulnerability groups (extremely vulnerable, highly vulnerable, vulnerable, at risk and resilient), depending on the score.[27] A standardised protocol was used to set thresholds for scoring on a 1 to 7 scale, including plotting new data, fitting data to possible distribution curves, correlating the indicator with country size, transforming and refitting data. Before setting scoring levels, it was tested whether an

26 Vulnerability is here defined as converse to resilience – "the extent to which the responder is able to resist damage/degradation by hazards" (Kaly / Pratt / Mitchell 2004, 35), with an unusual emphasis on resistance, while usually the ability to absorb changes is emphasised (Barnett / Lambert / Fry 2008).

Normally, resilience and vulnerability are connected but not exactly the opposite. *Resilience* describes "the ability of natural populations to return to their previous state following a shock" (Grafton et al. 2012, 294), usually measured by the time required to return to the previous state. *Vulnerability* expresses the "extent to which an environment or species is threatened or endangered by changes" (Grafton et al. 2012, 360).

27 The overall EVI score is the simple average of the individual indicators, but multiplied by one hundred. Hence, the scale ranges from 100 to 700, where 100 indicates high resilience and 700 indicates high vulnerability.

indicator was applicable to all countries, was correlated with country size, whether a scale transformation was necessary and what the trigger level – the level beyond which environmental conditions would be considered unsustainable – would be. Depending on the maximum and minimum values observed, the underlying distribution and the relationship between an indicator and environmental vulnerability, a specific number on the 1 to 7 scale was assigned to each range (e.g. $x < 3.5$ equals 1; $3.5 < x < 5$ equals 2; etc.).

Weighting and aggregation: The index is built by simple averaging across the indicators. In addition, a range of thematic sub-indices is constructed, including climate change, exposure to natural disasters, biodiversity, desertification, water, agriculture/fisheries, and human health aspects.

Uncertainty and sensitivity: The index was checked to be representative of global conditions – clustering similar countries closely and differentiating dissimilar countries sufficiently.[28]

Visualisation: For each country, the index is reported as a single dimensionless number, accompanied by separate scores for each aspect of vulnerability and for each sub-index. Country profiles present the results for all indicators, identifying the specific issues of vulnerability and resilience.

3.4.2 Evaluation

Content: The index covers environmental spheres related to the atmosphere (weather and air), lithosphere (land and vegetation) and hydrosphere (water and fisheries). Also, general aspects such as hazardous substances, waste and biodiversity are included.

The focus on the vulnerability of the natural environment in isolation, without accounting for the interdependencies with the social and economic environment, is particularly problematic when it comes to indicators such as volcanoes, earthquakes, tsunamis and dry spells – because it implies that *"the environment is a risk to itself"* (Barnett / Lambert / Fry 2008, 111). Therefore it seems that what is referred to as environment might really mean biota (Barnett / Lambert / Fry 2008). On the other hand, however, the authors specify environmental risks as any events or processes that can cause damage to the ecosystem integrity, including meteorological, geological and biological events, anthropogenic impacts, climate change and sea-level rise (Pratt / Kaly / Mitchell 2004) – both natural and human events.

The index is criticised for not capturing the underlying dynamics of vulnerability, in which a country's activities such as consumption patterns can affect the vulnerability of another country (Barnett / Lambert / Fry 2008). This critique is not convincing because it makes sense to attribute factors that increase vulnerability to the country where vulnerability is actually compromised – if the objective is to grasp the vulnerability of a country's natural environment, and not the driving factors.

28 It is planned to examine whether countries considered similar in characteristics ex ante are clustered together and to validate the scores against independent expert assessments (Kaly / Pratt / Mitchell 2004).

Barnett / Lambert / Fry (2008) criticise that population growth, fertilizers, coastal settlements, and tourism are exclusively framed as risks to the environment – because these processes may be the result of economic development – and that the qualitative nature of these processes is not considered – because their environmental damage may be different. Indeed, it makes sense to also account for qualitative, not only quantitative, differences. However, by classifying these indicators as hazards to the natural environment – regardless of the reason for them happening – Kaly / Pratt / Mitchell (2004) are consistent with their theoretical framework if the focus is on the vulnerability of the natural environment.

It has been suggested that one should assign different weights to indicators, depending on their relative importance for a given country (Barnett / Lambert / Fry 2008). It is certainly worth applying data envelopment analysis (DEA) in order to illustrate the best- and worst-case scenario for the different countries and to illustrate how they differ from the reference score. Yet, if the suggestion is to use DEA exclusively, this does not represent an improvement of the current technique, but rather suggests the usage of an entirely different technique – with different advantages and disadvantages.[29]

Technique: The underlying rationale and methodology of the EVI is extensively documented. The steps to construct the composite indicator are openly and transparently described. It seems that everything possible has been done to achieve a sound balance between the best available scientific information, methodology and expert knowledge. The authors explicitly mention the limitations of each indicator and make suggestions for improvement, where possible. They also suggest that the information for scaling and for the thresholds needs further improvement and refinement in the future (Kaly / Pratt / Mitchell 2004, 11). From a conceptual standpoint, the effort to embed the indicators in scientifically founded concepts or limits of sustainability is remarkable (Dahl 2007). Indicators are end-point indicators, which signal the results of a variety of conditions and processes. For instance, a high percentage of original forest cover indicates that maintenance processes of forest cover are intact – rather than measuring many indicators that may individually cause loss of forest cover. Thanks to the use of thresholds, the score of any individual indicator can be independently evaluated from any other. Likewise, any country can assess its environmental vulnerability independently from the score of any other country (Kaly / Pratt / Mitchell 2004).

The index suffers from some typical problems characteristic of composite indicators such as differing data quality between countries, difficulties with obtaining data, or using proxy indicators because data is lacking. What is more problematic is that the results of the index are seemingly affected by the indicators chosen (Kaly / Pratt / Mitchell 2004); a detailed assessment of this weakness, however, is impossible due to lack of information.

In constructing the index, two important steps have been skipped: imputation of missing data and multivariate analysis. First, only indicators with no missing data are used since missing or not-applicable data are not imputed. A common misunderstanding is that, if

29 For a detailed discussion of data envelopment analysis, see Cooper / Seiford / Tone (2007).

data are not available, no value is given – meaning that these indicators do not contribute to the index score for that country (e.g., Barnett / Lambert / Fry 2008). In actual fact, if a simple average is used and if the index score is correctly calculated, the missing indicators do contribute to the index score for that country; their contribution is equal to the average of the available indicators for that country because weights for the available indicators are rescaled to unity sum.[30] This is problematic because the average value is likely to not replace the missing values as accurately as an imputed value. The imputed value uses information (e.g., from previous years) directly related to the indicator which is likely to be a more accurate approximation than the average of the other indicators available. In addition, the decision to not impute missing data conflicts strongly with the request to have a complete data set without missing values, as suggested by the OECD (2008). Second, possible relationships between individual indicators have not been scrutinised by correlation analyses or a principal component analysis (PCA).[31] Such analyses help to identify redundant indicators and, thereby, to create a lean dataset.

Barnett / Lambert / Fry (2008) criticise the requirement of having data for 80 percent of the indicators in order to calculate a valid index score as arbitrarily selected and argue that it ignores the possibility that the 20 percent of missing indicators might be those that matter most. This data requirement should be seen in line with the above argument about missing values. The requirement means nothing more than, if up to 20 percent of the indicators have missing values, that the index score is calculated – and that these missing values will be inherently replaced by the average of the available indicators. As mentioned before, it is desirable to impute as little data as possible; the more complete the data are initially, the better. Replacing missing values by the average value may distort the index score if the average value is very different from the (theoretically) imputed value.

A cross-correlation analysis reveals some inconsistencies in the structure of the index (Table 6). All indicators are significantly and positively correlated with the dimension damage. Despite the significant positive correlation, it is apparent that several indicators are only weakly or moderately correlated with their dimension. In two cases, the indicator is more strongly correlated with a different dimension. The same is true for the correlations within the dimension resistance. The majority of correlation coefficients are significant and positive. Two indicators, however, are negatively correlated with their own dimension, but positively correlated with another dimension. The dimension hazards shows the weakest results. Many indicators are uncorrelated, weakly correlated or negatively correlated with the dimension; only a handful of indicators are strongly positively correlated with the dimension.

30 For instance, index ABC is constructed by indicators A, B and C. For country a, indicator A equals 5, indicator B is missing and indicator C equals 3. If the missing indicator B is not imputed, the index score is 4 for country a ((5+3)/2); the weights of indicators A and C correspond to 50 per cent. If the missing indicator B is replaced by the average of indicators A and C ((5+3)/2=4), the index score is still 4 ((5+4+3)/3); the weights of indicators A, B and C correspond to 33 per cent.

31 The goal is to reveal how different variables change in relation to each other and how they are associated. The underlying rationale is to explain the variance of the observed data through a few linear combinations of the original data (OECD 2008).

Table 6: Coherence test in the Environmental Vulnerability Index (EVI) framework

		Dimensions		
Dimensions	**EVI indicators**	**I**	**II**	**III**
I. Damage	Ecosystem imbalance	0.30***	0.17*	
	Introductions	0.51***		0.61***
	Endangered species	0.51***	-0.19**	0.85***
	Extinctions	0.47***		0.45***
	Natural vegetation cover remaining	0.42***		-0.20*
	Fragmented habitats	0.60***	0.51***	0.46***
	Degradation	0.55***	0.28***	
	Population density	0.85***	0.41***	0.39***
	Human populations	0.73***	0.43***	0.32***
	Human conflicts	0.13*		-0.39***
II. Hazards	High winds		0.24***	
	Dry periods	0.34***	0.23***	0.44***
	Wet periods	0.20**	0.33***	0.28***
	Hot periods	-0.15*	0.47***	-0.30***
	Cold periods	-0.23**	0.35***	-0.28***
	Sea temperatures		0.33***	-0.32***
	Cumulative volcano risk		0.20**	
	Cumulative earthquake energy		0.17**	
	Tsunami density	0.14*		0.20**
	Land slides		0.34***	
	Environmental openness	0.43***	0.77***	0.32***
	Loss of natural vegetation cover			
	Terrestrial reserves			
	Marine reserves		0.27**	
	Intensive farming	0.38***	0.47***	0.35***
	Fertilisers	0.50***	0.77***	0.20*
	Pesticides		0.51***	
	Biotechnology		0.43***	-0.18**
	Productivity overfishing		0.53***	-0.54***
	Fishing effort	0.37***		
	Renewable water	0.23**	0.29***	
	Sulphur dioxide emissions	0.43***	0.60***	0.15*
	Waste production			
	Waste treatment		**-0.39***	0.51***
	Industry	0.24**	0.67***	
	Spills		0.29***	
	Mining		0.23***	
	Sanitation	0.51***	0.27**	
	Vehicles	0.46***	0.67***	0.33***
	Population growth		**-0.29*****	
	Tourists	0.60***	0.34***	0.53***
	Environmental agreements		**-0.36*****	0.40***

Table 6 (cont.): Coherence test in the Environmental Vulnerability Index (EVI) framework				
		Dimensions		
Dimensions	EVI indicators	I	II	III
III. Resistance	Land area	0.45***	-0.20**	0.84***
	Country dispersion	0.46***		0.83***
	Geographic isolation	0.28***	-0.16*	0.78***
	Vertical relief	-0.21**	0.16*	**-0.30*** **
	Lowlands	0.22***	-0.14*	0.73***
	Shared borders		0.23***	**-0.19** **
	Migratory species	0.41***	-0.25***	0.83***
	Endemic species			0.50***

Notes: Cells in pink are the Pearson correlation coefficents of the variables with their own EVI indicator. Numbers in pink mark correlation coefficients that correlate higher across dimensions. Numbers in bold mark correlation coefficients that are negatively correlated with their dimension. Correlation coefficients that are non-significant at the 95%-level are printed in light grey.
***, **, and * denote significance at 0.1, 1, and 5 percent, respectively.

Source: Own elaboration

The coherence test between indicators and sub-indices illustrates inherent weaknesses (Table 7). Contrary to other indices, the indicators used to construct several sub-indices overlap to a great extent. Some indicators are used in up to five different sub-indices, while other indicators are not included in any. The simple correlation analyses illustrate the presence of trade-offs, random associations and the need to reorganise indicators.

Table 7: Coherence test in the Environmental Vulnerability Index (EVI) framework (sub-indices)								
		Sub-indices						
	EVI indicators	Climate change	Natural disasters	Human health	Agricul-ture and fisheries	Water	Desertifi-cation	Bio-diversity
I. Damage	Ecosystem imbalance	0.08	0.08	0.04	0.35***	-0.00	0.03	0.24**
	Introductions	0.44***	0.19**	0.20**	0.37***	0.32***	0.04	0.71***
	Endangered species	0.60***	0.12	0.19**	0.26***	0.42***	0.13*	0.80***
	Extinctions	0.24***	0.21**	0.05	0.16*	0.26***	0.11	0.55***
	Natural vegetation cover remaining	0.30***	-0.06	0.29***	0.20*	0.42***	0.29***	0.13
	Fragmented habitats	0.67***	0.50***	0.52***	0.65***	0.30***	0.26***	0.63***
	Degradation	0.18*	0.30***	0.29***	0.47***	0.59***	0.57***	0.14
	Population density	0.70***	0.57***	0.61***	0.58***	0.75***	0.26***	0.50***
	Human populations	0.63***	0.54***	0.47***	0.50***	0.57***	0.19**	0.47***
	Human conflicts	-0.26***	-0.05	-0.03	-0.06	0.03	-0.05	-0.31***
II. Hazards	High winds	0.29***	0.34***	0.04	0.12	-0.09	0.49***	-0.04
	Dry periods	0.43***	0.53***	0.17*	0.45***	0.53***	0.37***	0.42***
	Wet periods	0.41***	0.55***	0.14*	0.48***	0.43***	0.38***	0.25***
	Hot periods	0.24***	0.37***	0.22**	0.24**	-0.12	0.57***	-0.19*
	Cold periods	0.04	0.29***	0.06	0.15*	-0.18*	0.49***	-0.20**
	Sea temperatures	0.11	-0.02	0.22**	0.19**	-0.22**	0.06	-0.11
	Cumulative volcano risk	-0.07	0.34***	-0.06	0.02	-0.04	-0.05	-0.01

Table 7 (cont.): Coherence test in the Environmental Vulnerability Index (EVI framework) (sub-indices)								
		Sub-indices						
	EVI indicators	**Climate change**	**Natural disasters**	**Human health**	**Agriculture and fisheries**	**Water**	**Desertification**	**Biodiversity**
II. Hazards	Cumulative earthquake energy	-0.06	0.24***	-0.02	0.01	0.01	-0.02	0.01
	Tsunami density	0.06	0.26***	-0.01	0.07	0.05	0.03	0.21**
	Land slides	0.03	0.45***	0.02	0.17*	0.10	0.17*	-0.03
	Environmental openness	0.66***	0.64***	0.67***	0.74***	0.38***	0.45***	0.57***
	Loss of natural vegetation cover	-0.23**	-0.07	-0.19*	-0.12	0.39***	-0.04	0.01
	Terrestrial reserves	0.04	-0.14	-0.08	-0.13	0.19*	0.00	0.17*
	Marine reserves	0.16	0.02	0.13	0.28**	0.12	0.01	0.27**
	Intensive farming	0.40***	0.49***	0.32***	0.60***	0.33***	0.25***	0.38***
	Fertilisers	0.65***	0.66***	0.75***	0.75***	0.45***	0.43***	0.38***
	Pesticides	0.29**	0.33***	0.59***	0.48***	0.28**	0.42***	-0.07
	Biotechnology	0.03	0.34***	0.12	0.26***	-0.13	0.11	-0.11
	Productivity overfishing	-0.17*	0.22**	0.14	0.35***	-0.07	0.12	-0.36***
	Fishing effort	-0.01	0.12	0.13	0.22*	0.47***	0.02	-0.04
	Renewable water	0.46***	0.01	0.53***	0.25**	0.29***	0.48***	0.24**
	Sulphur dioxide emissions	0.53***	0.45***	0.85***	0.56***	0.36***	0.30***	0.28***
	Waste production	0.39**	0.01	0.13	0.02	0.01	0.03	0.08
	Waste treatment	-0.01	-0.30	0.12	-0.30	0.35*	-0.36*	0.35*
	Industry	0.46***	0.38***	0.54***	0.52***	0.11	0.27**	0.33***
	Spills	0.05	0.17*	0.09	0.12	0.06	0.12	-0.08
	Mining	-0.04	-0.06	0.20**	0.04	0.05	0.00	-0.03
	Sanitation	0.21*	0.25**	0.42***	0.29**	0.57***	0.06	0.16
	Vehicles	0.68***	0.52***	0.60***	0.65***	0.23**	0.32***	0.49***
	Population growth	-0.29***	-0.26***	-0.33***	-0.34***	0.15*	-0.25***	-0.10
	Tourists	0.66***	0.32***	0.50***	0.53***	0.42***	0.18*	0.63***
	Environmental agreements	0.16*	-0.29***	-0.09	-0.28***	0.06	-0.14*	0.25***
III. Resistance	Land area	0.69***	0.12	0.21**	0.25***	0.43***	0.18**	0.76***
	Country dispersion	0.68***	0.19**	0.21**	0.29***	0.37***	0.13*	0.79***
	Geographic isolation	0.40***	0.18**	-0.02	0.13	0.17**	0.15*	0.69***
	Vertical relief	-0.29***	0.05	-0.07	-0.13	-0.16*	0.09	-0.35***
	Lowlands	0.54***	0.08	0.10	0.10	0.11	0.24***	0.64***
	Shared borders	-0.16*	0.03	0.07	0.05	-0.06	0.02	-0.12
	Migratory species	0.63***	0.06	0.20**	0.28***	0.40***	0.17**	0.75***
	Endemic species	0.01	0.20**	-0.09	0.01	0.16*	-0.05	0.31***

Notes: The numbers in pink are the Pearson correlation coefficents of the variables with their own EVI indicator. Correlation coefficients that are non-significant at the 95%-level are printed in light grey.
***, **, and * denote significance at 0.1, 1, and 5 percent, respectively.

Source: Own elaboration

Country coverage: The EVI has the most extensive country coverage of all cross-national environmental indices analysed – including almost all developing countries. According to the above 80 percent-threshold, data for 27 developing countries are insufficient for valid scores (Kaly / Pratt / Mitchell 2004).

3.5 Environmental Wellbeing (Sustainable Society Index (SSI))

3.5.1 Framework

Background: Environmental Wellbeing is a dimension of the Sustainable Society Index, which measures the level of sustainability of a country and monitors progress to sustainability (Kerk / Manuel 2012). In total, the index contains 21 sub-indicators, aggregated into eight indicators, aggregated into an environmental, human and economic wellbeing dimension (see Figure 7). In particular, the dimension environmental wellbeing comprises three indicators: nature and the environment, natural resources, and climate and energy. The index is calculated for 151 countries. The index is included in the evaluation because one dimension focuses on measuring environmental wellbeing.

Data selection: Relevance and timeliness are the criteria for indicator selection.[32] Raw data are checked for reporting errors and outliers that could bias the results.

Imputation: The dataset has excellent data coverage, such that few data gaps are filled in by expert judgment.

Normalisation: Each sub-indicator is normalised using rescaling (min-max method) in order to convert different units, ranges and variances into a common scale.[33] All normalised indicators are expressed in a 1–10 scale, with 10 representing most sustainable.

Weighting and aggregation: Sub-indicators are aggregated into eight indicators by simple geometric mean. Each sub-indicator is assigned equal nominal weights due to lack of clear references as to the importance of each indicator in determining sustainability. The human, environmental and economic wellbeing dimensions are calculated as the geometric mean of the underlying indicators.

Multivariate analysis: The principal component analysis confirms the existence of a single latent dimension in each dimension. The cross-correlation analysis shows, first, that sub-indicators are more correlated to their own indicator than to any other indicator and, second, that indicators are more correlated to their own dimension than to any other dimension. The analysis also finds that all correlations within an indicator as well as within a dimension are significant and positive. This means that, firstly, neither sub-indicators nor indicators need to be reallocated into different indicators or dimensions respectively and, secondly, that no trade-offs are present (Saisana / Philippas 2012).

32 The following is based on the results of a comprehensive audit of the 2012 SSI by Saisana and Philippas from the Joint Research Centre (JRC) of the European Commission (Saisana / Philippas 2012).

33 Subtracts the minimum value and divides by the range of the indicator values (OECD 2008).

Figure 7: Structure of the Sustainable Society Index (SSI)

Name	Dimensions	No.	Indicators	No.	Sub-indicators	No.	Variables	No.
Sustainable Society Index (SSI)	Human wellbeing	1	Basic needs	1	Sufficient food	1		
					Sufficient to drink	2		
					Safe sanitation	3		
			Health	2	Healthy life	4		
					Clean air	5		
					Clean water	6		
			Personal and social development	3	Education	7		
					Gender equality	8		
					Income distribution	9		
					Good governance	10		
	Environmental wellbeing	2	Nature and environment	4	Air quality*	11	SO_2 emissions per capita	1
							SO_2 emissions per GDP	2
					Biodiversity	12	Size of protected areas (in % of land area)	3
			Natural resources	5	Renewable water resources	13	Annual water withdrawals as % of renewable water resources	4
					Consumption*	14	Ecological Footprint minus Carbon Footprint	5,6
			Climate and energy	6	Renewable energy	15	Renewable energy as % of total energy consumption	7
					Greenhouse gases	16	CO_2 emissions per capita per year	8
	Economic wellbeing	3	Transition	7	Organic farming	17		
					Genuine savings	18		
			Economy	8	Gross domestic product	19		
					Employment	20		
					Public debt	21		

* = Note that variables are already aggregate measures. Note that only the variables of the dimension environmental wellbeing are shown in detail.

Source: Own elaboration based on Kerk and Manuel (2012)

Uncertainty and sensitivity: The analysis of the weights reveals that most implicit weights are similar, although some implicit weights reveal that some sub-indicators are slightly more important than others, and that the marginal weights show that the index structure is balanced. Implicit weights capture the impact of sub-indicators on the variance of indicator scores and measure the expected reduction in variance of indicators if a sub-indicator could be fixed, while marginal weights of a sub-indicator express the elasticity of an indicator to a change in one sub-indicator, here a 10% increase, keeping other sub-indicators unchanged. Saisana and Philippas (2012) tested two alternative normalisation procedures – the z-scores approach versus the min-max method for normalising indicators – and tested different sets of indicator weights. The results show that country ranks on the three wellbeing dimensions depend mostly on the indicators used, not on the methodological judgments – choice of normalisation procedure and weights – made during the aggregation.

Decomposition: Decomposing the three dimensions revealed that countries with similar scores in one dimension can have notable differences in their performance within this dimension – inviting a closer look at the components (Saisana / Philippas 2012).

Visualisation: The results are presented comprehensively. Initially, the results are summarised at global and regional level as well as per income class. In a second step, figures, maps and rankings provide a detailed illustration for the index, wellbeing dimensions, indicators and sub-indicators.

3.5.2 Evaluation

Content: The index and its dimensions are well constructed as regards statistical coherence, while the conceptual coherence is not as convincing, particularly as regards the dimension environmental wellbeing. This dimension covers several environmental spheres: Air, climate, water, and biodiversity. The index includes a short presentation of the underlying theoretical framework, but does not explain the rationale why a specific indicator is used in the index. The target for each indicator is documented but not discussed – leaving room for interpretation. For instance, the target for the indicator on biodiversity is to protect 20% of available land area – the officially discussed target some years ago. Due to the limited documentation of the data used for the index, the reasons for defining this target are ambiguous, as is the rationale to use this indicator to reflect biodiversity. Firstly, the new internationally agreed Aichi Targets for conservation are 17% for terrestrial and inland water, and 10% of coastal and marine areas. Secondly, the focus on protected land area is insufficient because it does not represent the actual quality of protection. Certain criteria need to be fulfilled if an area is to become a protected area, but they are not mentioned.[34] The name of the indicator on greenhouse gases is misleading. It only reflects the carbon dioxide emissions per capita per year which means that other greenhouse gas emissions, such as methane or nitrous oxide, are not included.

Technique: Had the technical evaluation to be exclusively based on the information published in the Sustainable Society Index report, it would be very rudimentary – because the report lacks any details about data quality, normalisation, weighting and aggregation. This information is by and large only found in the detailed assessment of the Sustainable Society Index carried out by the Joint Research Centre (JRC) of the European Commission (Saisana / Philippas, 2012). They find that, from a statistical perspective, the index seems to be well-constructed because country ranks are not driven by methodological assumptions and weights do not need any adjustment. However, combining the components of human, environmental and economic wellbeing into an overall index by calculating an average is not recommended: Significant negative correlations between different categories indicate in many cases a trade-off of human and economic wellbeing at the expense of environmental wellbeing.

34 Alternatively, the percentage of the total area of sites, identified as last refuge of one or more of the world's most highly threatened species, within protected areas may be used, as is done by the EPI (Emerson et al. 2012).

Table 8: Coherence structure in the dimension Environmental Wellbeing			
Sub-Indicators (Environmental wellbeing)	Indicators (Environmental wellbeing)		
	Nature and environment	Natural resources	Climate and energy
Air quality	0.62***	0.28***	0.50***
Biodiversity	0.84***	0.12	0.11
Renewable water resources	0.44***	0.58***	0.39***
Consumption	-0.09	0.69***	0.42***
Renewable energy	0.33***	0.49***	0.96***
Greenhouse gases	0.16*	0.62***	0.87***
***, **, and * denote significance at 0.1, 1, and 5 percent, respectively.			
Source: Own elaboration			

A detailed analysis of the correlation structure within and across sub-indicators and indicators (Table 8), that are part of the dimension Environmental Wellbeing, reveals that all sub-indicators are more correlated to their own indicator than to the other indicators. All correlations within one indicator are significant and positive. Consequently, no reallocation of sub-indicators is needed and no trade-offs are present.

Country coverage: Many developing countries on all continents are included in the ranking, with the exception of Oceania. Almost all low income countries are covered.

3.6 Living Planet Index (LPI)

3.6.1 Framework

Background: The Living Planet Index monitors changes in the status of biodiversity by measuring population trends of vertebrate species living in terrestrial, freshwater, and marine ecosystems around the world (WWF et al. 2012). Biological diversity is *"the variability among living organisms from (...) terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."* (UN 1992, Art. 2). Biodiversity is important for ecosystem resilience and evolutionary potential because diverse gene pools provide greater capacity for adaptation and help to maintain the ecosystem's structure (Perman et al. 2011). Biodiversity also plays a vital role in achieving human development (UNEP 2012).

The Living Planet Index uses changes in abundance in selected species *"as one important indicator of the planet's ecological condition."* (WWF et al. 2012, 18). It is a population abundance-based index, based on a small set of species selected to represent major groups (Biggs et al. 2007), namely on the change in size of over 9,000 populations of almost 2,700 mammal, bird, reptile, amphibian and fish species, relative to 1970, from around the globe (WWF et al. 2012, 18).[35] The advantage of abundance-based indicators is that they are sensitive to changes in abundance and caution against impending loss because the underlying information is continuous (Biggs et al. 2007)

Data selection: All data used are time series of population size, density, abundance or a proxy of abundance (WWF et al. 2012). Data are only included if a measure of population size is available for at least two years, if information on data collection, units of measure-

35 There are about 4,500 mammals, 9,700 birds, 4,000 amphibians and 6,550 reptiles (Perman et al. 2011, 29).

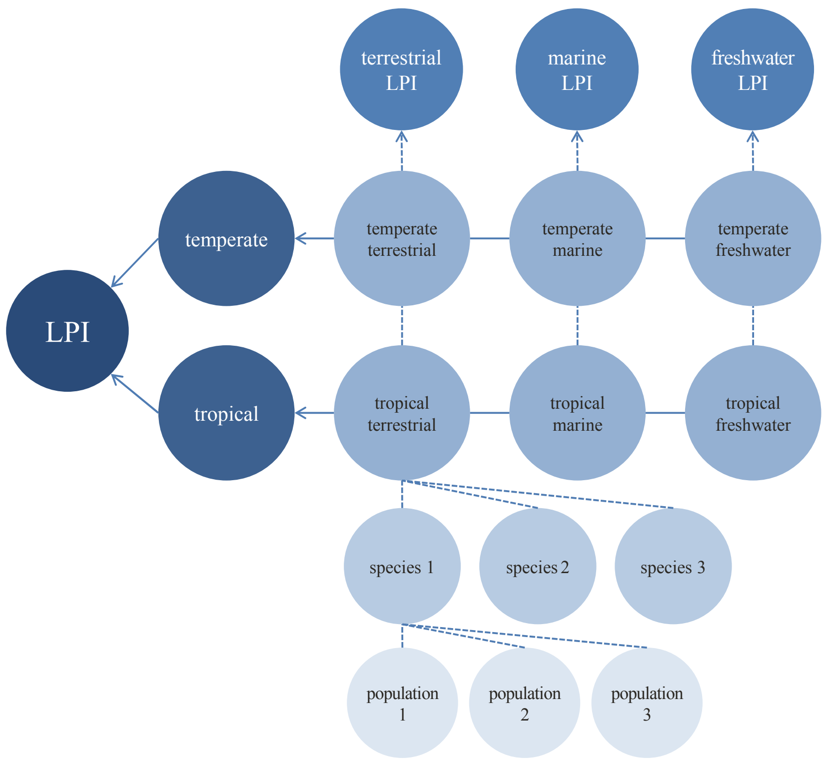
ment and geographic location of the population is provided, if the same collection method on the same population is used throughout the time series, and if the data source is referenced and traceable (Collen et al. 2009). The quality of each time series is determined according to the type of source, the type of method, and whether or not a measure of variation was calculated.

Imputation: Missing values were imputed with log-linear interpolation; none were extrapolated. The effect of variation in data quality on index trajectory and the impact of equally weighting population within species were examined.

Normalisation: The variables are not normalised because all variables represent changes of numbers of species (Böhringer / Jochem 2007).

Weighting and aggregation: First, the average rate of change in each year is calculated across all populations of a species, then across all species (Collen et al. 2009; WWF et al. 2012). Populations are weighted equally within species, and species are weighted equally within each index – with one exception. The average annual rates of change in successive years are chained, with the index value for 1970 as base-year scaled to unity. Each species is classified as being terrestrial, freshwater or marine, depending on which system is crucial for survival and reproduction. The terrestrial, marine and freshwater indices as system LPIs are calculated by giving equal weight to temperate and tropical species within each system, using the geometric mean (see Figure 8). The tropical and temperate indices as realm LPIs are calculated by giving equal weight to each species in the specific geographic location, using the geometric mean. The tropical and temperate indices are given equal weight in the global index, using the geometric mean.

Figure 8: Structure of the Living Planet Index (LPI)



Source: Own elaboration based on WWF et al. (2012, 19)

Uncertainty and sensitivity: The effect of variation in data quality and of equally weighting populations within species (regardless of true representation in the global population) were examined (Collen et al. 2009). Also, confidence limits (95% values around the mean) around index values were generated by a bootstrap resampling technique.

Visualisation: The graphical presentation includes the average global Living Planet Index, differences between terrestrial, freshwater, and marine species as well as biogeographical disaggregation by realm, by biome, and taxonomic disaggregation within habitat.

3.6.2 Evaluation

Content: The index aims to cover the environmental sphere biodiversity, but is only limitedly able to do so due to data constraints – which are related to general problems with data and knowledge on biodiversity. The major limitation of the index is related to the scope of the data. Data are restricted to vertebrates, with disproportionately more birds and mammals and fewer amphibians, reptiles and fish, and more abundant on temperate regions, with less data from tropical regions. The bias towards vertebrates and temperate regions is caused by the available data that is more abundant on populations in better-studied regions (Collen et al. 2009). The index does not include any data on flora, an important component of biodiversity, because there are few data available on the global distribution of plants, although they are relatively well documented (Pereira / Cooper 2006). As a result, it seems problematic to use data changes in abundance of vertebrates for general conclusions on the status of biodiversity for several reasons. The extent of biodiversity is poorly understood as the number of currently existing species *"is not known even to within an order of magnitude"* (Perman et al. 2011, 29).[36] The link between trends in vertebrate species and broader biodiversity is still largely unknown (Collen et al. 2009). Finally, the understanding of the causal links between biodiversity and ecosystems is limited, including the fact that critical limits of diversity are unknown (Biggs et al. 2007).

Technique: The composition of the index is technically sound, following many of the ten steps included in the suggested framework: The data are carefully selected; relatively few data are missing, requiring little imputation; aggregation accounts for non-compensability across indicators; uncertainty and sensitivity analyses are conducted. Yet, the weighting technique has been criticised for weighting equally all decreases in population size, regardless of whether the decrease brings a population close to extinction (Pereira / Cooper 2006). The scarcer a population is, specifically, the closer a population is to extinction, the more precious it becomes. Hence, equal weights do not reflect the greater importance of a population close to extinction, compared to a more abundant population.

Country coverage: The LPI is primarily available at global level; national LPIs were only calculated for Norway, Canada and Uganda.[37]

---

36 According to current knowledge, vertebrate animals represent only a small fraction of biodiversity as there are 270,000 plant species and 950,000 insect species described (Perman et al. 2011, 29; based on Jeffries (1997), based in turn on Groombridge (1992) and Heywood (1995)).

37 Personal communication with Louise McRae on 5 August 2013.

4 Synthesis: What are the comparative strengths and weaknesses of existing cross-country environmental indices in measuring the state of the environment?

After the detailed individual assessment, in the following the strengths and weaknesses are compared with respect to the three evaluation criteria: First, the overall concept and the coverage of environmental spheres; second, the technique and the theoretical framework; and third, the country coverage of particularly developing countries.

4.1 Content

The six environmental indices measure different environmental concepts, virtually all in national averages. No single existing cross-country environmental index measures the state of the environment. The concepts are related to the state of the environment, but are not identical with the state of the environment. Many indices include related dimensions and use similar or even identical variables – but not necessarily to measure exactly the same dimension. Some sub-indices measure environmental stresses for human health, also known as environmental health.

The EPI measures environmental stresses to human health as well as ecosystem health and natural resource management, whereas its predecessor ESI accounted for the ability of countries to protect the environment in the future. These two are the only cross-country environmental indices that include environmental health in the measurement. Vulnerability and resilience of "natural environments" to future shocks are the focus of the EVI. In turn, the EWI measures environmental quality in order to juxtapose it with the quality of life. The Environmental Wellbeing dimension of the Sustainable Society Index reflects the wellbeing of the environment – in addition to economic and social wellbeing. The Living Planet Index, finally, indicates the state of global biodiversity almost exclusively at global level.

Table 9 summarises the underlying concept, the technical framework as wells as strengths and weaknesses of the environmental composite indicators included in this analysis.

In content, the breadth of environmental composite indicators varies. Table 10 classifies the variables of each index into the three environmental spheres, cross-cutting issues (e.g., biodiversity) and the link to human wellbeing.[38] It becomes apparent that all indices contain at least one indicator of each environmental sphere; the LPI, by definition, is focused on biodiversity. Environmental health, reflecting stresses to human health caused by negative environmental conditions, is included in a couple of indices. Three environmental aspects – air, water and biodiversity – are included in virtually all composite indicators. If one exemplarily scrutinises some indicators and variables respectively, challenges relating to the environmental data available manifest themselves. For instance, the indicator on air

38 Note that for evaluating the coverage of environmental spheres, only those environmental aspects are marked that are directly covered by an indicator of the respective category in Table 10 (e.g. biodiversity may be understood as an end-point indicator which reflects the state of many other environmental indicators such as forests, water, fisheries etc.).

Table 9: Comparison of environmental indices

Name	**Ecosystem Wellbeing Index (EWI)**	**Environmental Performance Index (EPI)**	**Environmental Sustainability Index (ESI)**	**Environmental Vulnerability Index (EVI)**	**Environmental Well-being (Sustainable Society Index (SSI))**	**Living Planet Index (LPI)**
Source	Prescott-Allen 2001	Emerson et al. 2012	Esty et al. 2005	Kaly, Pratt and Mitchell 2004	Kerk and Manuel 2012	WWF et al. 2012, Collen et al. 2008
Developer(s)	Prescott-Allen 2001	Yale University; Columbia University	Yale University; Columbia University	SOPAC	Kerk and Manuel 2012	WWF
Concept measured	Measures diversity and quality of the ecosystem – in order to juxtapose it with the quality of life	Environmental health and ecosystem vitality	Ability of countries to protect the environment in the future	Vulnerability of "natural environment" to future natural and anthropogenic shocks	Wellbeing of the environment; (SSI measures and monitors health of coupled human-environmental systems at national level)	Status of biodiversity
Description	The EWI aims to measure the diversity and quality of the ecosystem and of the main pressures on them.	The EPI tracks outcome-oriented indicators on environmental issues. It centers on the measurement of environmental stresses to human health as well as ecosystem health and natural resource management. It benchmarks each country's performance on any indicator, using the proximity-to-target method.	The ESI benchmarks a country's performance in terms of environmental sustainability; it reflects a country's present environment quality, capacity to maintain and scope to improve conditions in the future.	The EVI estimates country profiles in terms of the resilience and vulnerability of environmental systems and resources to future shocks.	(The SSI measures a country's level of sustainability and progress to sustainability. Aims to describe societal progress along all three dimensions of sustainability.)	The LPI measures population trends of nearly 2,700 vertebrate species living in terrestrial, freshwater, and marine ecosystems around the world, relative to 1970. The index is a time series of either population size, density, abundance or a proxy of abundance.
Main dimensions	1) Land, 2) Water, 3) Air, 4) Species and genes, 5) Resource use	1) Environmental health, 2) Ecosystem vitality	1) Environmental systems, 2) Reducing environmental stresses, 3) Reducing human vulnerability, 4) Social and institutional capacity, 5) Global stewardship	1) Damage, 2) Hazards, 3) Resistance	1) Nature and environment, 2) Natural resources, 3) Climate and energy	1) Tropical and temperate indices, 2) Terrestrial, marine and freshwater indices
Year(s) of publication	2001	2012, 2010, 2008, 2006	2005, 2002, 2001, 2000	2004	2012, 2010, 2008, 2006	Last published in 2012; biennial publication
Country coverage (no. of developing countries (DCs))	180 countries (132 DCs)	132 countries (88 DCs)	146 countries (107 DCs)	235 countries (137 DCs)	151 countries (110 DCs)	–

Table 9 (cont.): Comparison of environmental indices

Name	Ecosystem Wellbeing Index (EWI)	Environmental Performance Index (EPI)	Environmental Sustainability Index (ESI)	Environmental Vulnerability Index (EVI)	Environmental Well-being (Sustainable Society Index (SSI))	Living Planet Index (LPI)
Structure	5 dimensions, 10 indicators, 16 sub-indicators, 51 variables	2 dimensions, 10 indicators, 22 variables	5 dimensions, 21 indicators, 76 variables	3 dimensions, 50 indicators, 50 variables	1 dimension, 3 indicators, 6 sub-indicators, 8 variables	2 dimensions, 6 indicators, 2,688 sub-indicators (= species), 9,014 variables (= populations)
Environmental spheres	Air, climate, land, soil, forests, water, fisheries, (chemicals), biodiversity	Air, climate, forests, water, fisheries, biodiversity, environmental health	Air, climate, land, forests, water, fisheries, waste, biodiversity, environmental health	Weather, air, land, (forests), water, fisheries, (chemicals), waste, biodiversity	Air, climate, water, biodiversity	Biodiversity
Scale	National	National	National	National	National	Global (national)
1. Data selection	If possible, representative, reliable, and feasible	Relevance, performance orientation, established scientific methodology, data quality, time series availability, completeness	Country size, variable coverage, indicator coverage – for countries, not indicators or variables	End-point indicators; balanced across different elements and ecological processes	Relevance, timeliness	Measure of population size available for at least two years; information on data collection, units of measurement, and geographic location of the population provided; referenced and traceable data source
2. Imputation of missing data	- Missing or not applicable data are not imputed - "Insufficient data rule" prevents high scores resulting merely from a lack of data	Missing values imputed or extrapolated	Two-step: 1. Before imputation, logarithmic or power transformation, if variable very skewed; 2. After imputation, variables transformed back to original scale; except extremely skewed variables. Markov Chain Monte Carlo simulation to substitute missing values with plausible quasi-random draws from their conditional distribution given the observed data. Some variables not imputed but replaced by the average of all values in each cell in the data matrix. Plus winsorisation	Missing or not applicable data are not imputed	Excellent data coverage; few gaps filled in by expert judgment	Log-linear interpolation

Table 9 (cont.): Comparison of environmental indices

Name	Ecosystem Wellbeing Index (EWI)	Environmental Performance Index (EPI)	Environmental Sustainability Index (ESI)	Environmental Vulnerability Index (EVI)	Environmental Well-being (Sustainable Society Index (SSI))	Living Planet Index (LPI)
3. Normalisation	Categorical scale with 5 bands (best = 100, worst = 0)	Logarithmic transformation; distance to a reference (min-max); best = 100, worst = 0	z-scores	Each variable transformed after standardized protocol into 1 to 7 scale; sustainability threshold; aim = 1 worst = 7	Min-max method (1–10 scale; 1 = low, 10 = high)	No normalisation [Ratio: (xi,t)/(xi,t-1)]
4. Weighting	Unweighted average, weighted average, veto; subjective (not derived)	30% Environmental health, 70% Ecosystem vitality	Equal weights across indicators, not components; variables within each indicator also weighted equally	Equal weights	Equal nominal weights	Equal weights (with exception of African mammals)
5. Aggregation methods	Arithmetic average across components (variables, indicator-subelements, indicators, dimensions)	Arithmetic average across indicators	Arithmetic average across indicators	Arithmetic average across indicators	Geometric mean across sub-indicators as well as indicators	Geometric mean across ratios
6. Multivariate analysis	–	Principal-Component-Analysis (by JRC)	Principal Component Analysis, stepwise linear regression, cluster analysis	–	Principal Component Analysis, cross-correlation analysis (by JRC)	–
7. Uncertainty and sensitivity	–	(by JRC for 2010 EPI)	By the JRC: Variability in the imputation of missing data; equal vs. experts opinion weighting of indicators; aggregation at indicators vs. at components level; linear vs. non-compensatory aggregation scheme	- Scoring for indicators is global - Similar countries clustered together (planned) - Validation against expert assessments (planned)	Choice of normalisation and weights (done by JRC): country ranks depend mostly on indicators used	Effect of variation in data quality and impact of equally weighting populations within species on index examined; confidence limits for percent change in species
8. Decomposition	–	–	–	–	Countries with similar scores in a dimension can perform very differently in that dimension (by JRC)	–

Table 9 (cont.): Comparison of environmental indices

Name	Ecosystem Wellbeing Index (EWI)	Environmental Performance Index (EPI)	Environmental Sustainability Index (ESI)	Environmental Vulnerability Index (EVI)	Environmental Well-being (Sustainable Society Index (SSI))	Living Planet Index (LPI)
9. Links to other indices	Compared to Ecological Footprint	–	Compared to Ecological Footprint Index, Environmental Vulnerability Index, and an index built out of Millennium Development Goal 7's indicators	–	–	–
10. Visualisation of results	Square graphic, staircase graphic; Barometer of Sustainability	Figures	Maps, tables (plus comprehensive presentation in different categories)	Tables, country profiles	Maps, figures	Tables, figures, maps (WWF et al.); Figures (Collen et al.)
Strengths	- Presentation of results is user-friendly and easy-to-read - All steps and decisions taken are documented - Balance between ecosystem and human conditions illustrated in a very intuitive way (Barometer of Sustainability)	- Mostly a statistically coherent and balanced index - Clear and transparent documentation of different steps to build index - Strict requirements for data - Materiality thresholds applied to account for varying natural resource endowments, physical characteristics, and geography	- Benchmarks performance as regards environmental sustainability - Strongly improved statistical foundation (compared to earlier versions)	- First measurement of environmental vulnerability - Each indicator is related to sustainability threshold - Based on theoretical framework - Incorporates data on different reponse scales and non-linearities	- Index convinces statistically and conceptually	- Simple yet appealing way of conveying information about changes in biodiversity trends to nonexperts - Abundance-based index: sensitive to change; provides advance warning of impending loss - Many data of long and full time series, requiring little interpolation
Weaknesses	- Mix of several aggregation methods - Veto method disguises contribution of variable to aggregate - Relative scaling of results - Scaling of each indicator affected by international standards, targets, expert opinion etc. - Some variables theoretically considered, but not implemented due to missing data	- No clear-cut definition of term environmental performance - Some aspects could not be covered due to significant gaps in environmental data - Two main dimensions should not be aggregated into a single index - Debatable whether dimension environmental health measures impact of environmental conditions on human health	- Mixes variables and indicators from different parts of causal chain - Biased to developed countries - Equal weighting of indicators is arbitrary and may be inappropriate - Impossible to summarize environmental sustainability in a single index; multitude of aspects related to the environment	- Some environmental factors are represented by proxy indicators; some data difficult to obtain - Results affected by the indicators chosen - Problems with differing data quality between countries - Emphasizes short-term environmental change - Model focuses on the national scale; local variations are not incorporated	- Targets for each indicator are not thoroughly discussed - Rationale for indicator usage is unclear	- Data coverage restricted to vertebrates - Tropical populations less covered than temperate populations - Variation in the nature of underlying data can cause change in trend - All decreases in population size weighted equally

Source: Own elaboration.

quality, used in SSI and EPI, is the aggregate of sulphur dioxide emissions per capita and per GDP. These two variables are based on estimates of anthropogenic global sulphur dioxide emissions calculated by Smith et al. (2011), where the last estimates available are for the year 2005. Moreover, conditional on a more efficient usage, emissions per GDP might induce a bias against developing countries. The variables on water resources illustrate a different challenge; for instance, change in water quantity (EPI) as the area-weighted percent reduction of mean annual river flow from 'natural' state owing to water withdrawals and reservoirs; or renewable water resources (Environmental Wellbeing, SSI) as annual water withdrawals per capita as a percentage of renewable water resources. These variables reflect the average at national level, but cannot represent water scarcity for specific groups or regions which depends on seasonal and regional variability as well as technical and financial capacity for resource use.

Table 10: Coverage of environmental spheres of environmental indices

	Environmental sphere										Cross-cutting issues			Link to human well-being
	Atmosphere			Lithosphere			Hydrosphere							
	Weather	Air	Climate	Land	Soil	Forests	Water	Rivers	Oceans	Fisheries	Chemicals	Waste	Biodiversity	Environmental health
Ecosystem Wellbeing Index		x	x	x	x	x	x	x (river conversion)		x	x (water)		x	
Environmental Performance Index		x	x	x (agricultural subsidies)		x	x	x (water quantity)		x	x (pesticide regulation)		x	x
Environmental Sustainability Index		x	x	x	x	x	x			x		x	x	x
Environmental Vulnerability Index	x	x		x		x (vegetation)	x			x	x (hazardous substances)	x	x	
Environmental Wellbeing (Sustainable Society Index)		x	x				x						x	
Living Planet Index													x	

Source: Own elaboration[39]

Biodiversity is the cross-cutting issue which is covered by all environmental indices. Table 11 illustrates the variety of variables subsumed under the same indicator biodiversity; with the exception of the EWI referring to the 'wild diversity index' and the 'domesticated diversity index'.

39 Note that information in brackets is given if variable is limited to specific context.

Table 11: Variables used for indicator biodiversity	
Index	**Variables**
Ecosystem Wellbeing Index (EWI)	Threatened plant species (% of total plant species) Threatened animal species (% of total animal species) No. of not-at-risk breeds of a species/mio. head of species Threatened breeds of species/not-at-risk breeds of species
Environmental Performance Index (EPI)	Critical habitat protection Biome protection Marine protected areas
Environmental Sustainability Index (ESI)	% of country's territory in threatened ecoregions Threatened bird species as % of known breeding bird species in each country Threatened mammal species as % of known mammal species in each country Threatened amphibian species as % of known amphibian species in each country National Biodiversity Index
Environmental Vulnerability Index (EVI)	No. of endangered and vulnerable species No. of species known to have become extinct since 1900
Source: Own elaboration	

4.2 Technique

Although the composite indicators analysed in this evaluation are similar in scope, they are distinct in concept, measurement and their time horizon. Each environmental index is embedded in the 10-steps-framework (see Section 2.2), although no single index follows the complete procedure and not to the same degree.

The most apparent similarity is that all composite indicators measure the respective construct at national or global level. As a consequence, neither the variables as a basis nor the index as a result reflects local variations.

Many indices use the arithmetic (weighted or unweighted) average as an aggregation method. The arithmetic mean has significant implications for the relationship between the variables of an indicator, the indicators of a dimension, or the dimensions of an index. Linear aggregation implies perfect substitutability, wherein the rate of substitution between one dimension and another dimension is constant. In other words, poor performance in one component, such as air quality, can be offset by good performance, such as water quality, in another component, regardless of the level of each variable (Klugman / Rodríguez / Choi 2011; OECD 2008). If the nature of the concept that ought to be measured requires an aggregation technique that implies imperfect substitutability between variables, indicator, or dimensions, respectively, the geometric mean may be an appropriate alternative. The geometric mean implies only partial substitutability, rewards balance by penalising uneven performance between indicators, and provides incentives for improvement in the weak components (Saisana / Philippas 2012).

Two indices, the EVI and the EWI, do not impute missing or not-applicable data – with practical implications for constructing a composite indicator. As the simple arithmetic average is used, the missing data is replaced by the average of the available data for each country.

In addition, indices are different according to their type of measurement. Some indices measure the level, while others measure the change. This difference is also reflected in the time-horizon: some indices follow a short-term approach, providing a snapshot, while others have a long-term perspective, focusing on a trend.

4.3 Country coverage

The environmental indices cover some, but not all, developing countries. Asia, Europe and the Americas are usually well covered. The coverage of Oceania and the African continent varies most strongly among indices (see Table 12).

Table 12: Country coverage

	Index	Ecosystem Wellbeing Index	Environmental Performance Index	Environmental Sustainability Index	Environmental Vulnerability Index	Environmental Wellbeing (SSI)	Total
Region	Africa	52	27	42	52	42	53
	Asia	34	29	32	34	32	36
	Europe	11	12	12	11	13	14
	Americas	29	21	22	28	22	29
	Oceania	6	0	1	12	1	12
Income category	Low income	36	16	32	36	32	36
	Lower-middle income	47	32	36	50	36	54
	Upper-middle income	49	41	43	51	42	54
	Total	132	89	109	137	110	144

Notes: Only developing countries (non-high-income countries) are included. Income definition according to World Bank. Region definition according to United Nations. Always last edition of each index.

Source: Own elaboration

5 Conclusion and outlook: Which lessons have we learned and where do we go from here?

This evaluation reviews six cross-country environmental composite indicators. The analysis focuses on methodology, concept and coverage of developing countries. Here the aim is to evaluate which information about the environment is available from a comparative perspective, particularly in developing countries. The first criterion is to analyse the concept used to define the multidimensional phenomenon related to the state of the environment. The second is to focus on the methodology employed in constructing an index in order to assess its technique, robustness and interpretation. The third aspect to be evaluated is the extent to which developing countries, defined by income, are included in each index. The most significant lessons learned are then summarised, while the prospect of cross-country environmental composite indicators is briefly commented on.

Six environmental composite indicators measure the state of the environment, or an aspect thereof, in developing countries in a cross-country setting. Comparing conceptual soundness, technical soundness (relating to sector A, B and C in Figure 2) and country coverage, it becomes apparent that each cross-country environmental index has its strengths and weaknesses (see the summary in Figure 9):

– **Conceptually interesting, ample coverage, but lacking technical soundness**: Two indices, the Environmental Vulnerability Index (EVI) and the Ecosystem Wellbeing Index (EWI), attempt to measure highly relevant concepts. Particularly the former pursues a concept that is difficult to implement. Both cover many environmental aspects. The EWI covers almost all developing countries. These indices are not fully convincing as regards technical aspects however, as they do not impute missing data but replace missing data by the average of the data available.

– **Conceptually and technically interesting, but outdated**: The Environmental Sustainability Index (ESI) is very interesting from a conceptual point of view: The steps taken in constructing the index were sophisticated. Yet, the wide range of indicators complicated their aggregation into an overall score. Some indicators induced bias against developing countries. The overall score was calculated as a relative score, which limited the comparability of the index. – Thus this index was replaced for good reasons by its successor Environmental Performance Index.

– **Conceptually and technically sound, but covering restricted country sample**: The Environmental Performance Index (EPI) is a very well-constructed composite indicator. In particular, the dimension on ecosystem vitality is well composed. The dimension on environmental health is less well composed, mainly due to lack of data for more appropriate indicators. The index is not in a position to cover developing countries comprehensively, especially in Africa, because its data requirements are very strict.

– **Technically sound, but less interesting from a conceptual perspective**: The Environmental Wellbeing dimension of the Sustainable Society Index (SSI) is technically well constructed, but is conceptually limited because it does not cover environmental aspects extensively.

– **Technically sound, but measuring only at global level**: The Living Planet Index (LPI) is no comprehensive environmental composite indicator because it focuses exclusively on biodiversity. So far, the index is constructed at global scale only, with few exceptions at national level.

Monitoring environmental conditions is important, given the many interdependencies between human and environmental wellbeing. Environmental composite indicators allow countries to assess their status and, if measured regularly, to examine changes over time – broadly or very specifically. The challenge is to develop a theoretically and conceptually sound index which can be applied globally, implying the use of reliable and commonly accepted indicators. Depending on the underlying theoretical framework, country profiles may guide priority setting and policy action. Measuring environmental conditions needs to be done more in developing countries in order to strengthen the available data and enhance the knowledge base. The most meaningful measurement of the state of the environment is to define and use thresholds and target values. Such thresholds and target values allows one to

Figure 9: Summary evaluation

	Ecosystem Wellbeing Index (EWI)	Environmental Performance Index (EPI)	Environmental Sustainability Index (ESI)	Environmental Vulnerability Index (EVI)	Environmental Wellbeing (SSI)	Living Planet Index (LPI)
Content	broad	specific	very broad	very broad	limited	very specific
Framework						
Technical aspects	+	+++	++	+	(++)(2)	+++
Robustness	NA	(++)(1)	(++)	+	(++)	++
Interpretation and presentation	++	++	++	++	(++)(3)	++
Country coverage	+++	+	++	+++	++	NA

() = done by Joint Research Centre (JRC); (1) done by JRC for 2010 EPI; (2) multivariate analysis done by JRC; (3) decomposition done by JRC

Source: Own elaboration

assess the gap between the current result and the target. Yet, the definition of these targets is inevitably subjective and therefore highly contentious – as is the ongoing debate about which indicators are best suited to reflecting good environmental conditions.

By definition, environmental conditions measured at national level fail to cover local variations. And yet, local variations in the state of the environment can be considerable – that is, possible negative consequences for humans are likely to be more severe in areas where the state of the environment is particularly poor compared to areas where the state of the environment is better. It is desirable to have fine-grained knowledge of environmental conditions at local level. Yet, for the time being, the available data is fairly limited, particularly in developing countries, impeding sub-national measurement.

To sum up, there is no "perfect" cross-country environmental composite indicator – meaning here a composite indicator that is methodologically and conceptually sound and covers all (developing) countries. However, although they are not perfect, these cross-country environmental indices are still extremely useful. They reflect the state of the environment, or an aspect thereof, through national averages. Information on the current state of the environment is crucial because environmental problems strongly affect the opportunities of human development. Furthermore, measuring changes over time can have important policy implications such as flagging urgent needs for improvement, or measuring progress made.

Bibliography

Barnett, J. / S. Lambert / I. Fry (2008): The hazards of indicators: insights from the environmental vulnerability index, in: *Annals of the Association of American Geographers* 98 (1), 102–119

Bassi, A. M. / S. Fulai (2012): Green economy : measuring progress towards a green economy (draft working paper); online: http://www.unep.org/greeneconomy/Portals/88/documents/research_products/MeasuringProgress.pdf (accessed 08 Dec. 2013)

Biggs, R. et al. (2007): Biodiversity indicators, in: T. Hák / B. Moldan / A. L. Dahl (eds.), Sustainability indicators : a scientific assessment, Washington, DC: Island Press, 249–270 (SCOPE Report 67)

Böhringer, C. / P. Jochem (2007): Measuring the immeasurabel : a survey of sustainability indices, in: *Ecological Economics* 63 (1), 1–8

Borucke, M. et al. (2013): Accounting for demand and supply of the biosphere's regenerative capacity : the national footprint accounts' underlying methodology and framework, in: *Ecological Indicators* 24, 518–533

Carmines, E. G. / J. Woods (2004): Index, in: M. S. Lewis-Beck / A. Bryman / T. F. Liao (eds.), Encyclopedia of Social Science Research Methods, Vol. 2, Thousand Oaks, Calif.: Sage Publications, 485–486

Collen, B. et al. (2009): Monitoring change in vertebrate abundance : the living planet index, in: *Conservation Biology* 23 (2), 317–327

Cooper, W. W. / L. Seiford / K. Tone (2007): Data envelopment analysis : a comprehensive text with models, applications, references and DEA-solver software, New York: Springer

Dahl, A. L. (2007): Integrated assessment and indicators, in: T. Hák / B. Moldan / A. L. Dahl (eds.), *Sustainability indicators : a scientific assessment,* Washington, DC: Island Press, 163–187 (SCOPE Report 67)

Diener, E. / E. Suh (1997): Measuring quality of life : economic, social, and subjective indicators, in: *Social Indicators Research* 40 (1–2), 189–216

EEA (European Environmental Agency) (2005): EEA core set of indicators : guide, Luxembourg

– (2013): Indicators; online: http://www.eea.europa.eu/data-and-maps/indicators/#c5=&c7=all&c0=10&b_start=0 (accessed 16 Aug. 2013)

Emerson, J. W. et al. (2012): 2012 environmental performance index and pilot trend environmental performance index, New Haven, Conn.: Yale Center for Environmental Law and Policy

Esty, D. C. et al. (2005): 2005 environmental sustainability index : benchmarking national environmental stewardship, New Haven, Conn.: Yale Center for Environmental Law and Policy

– / M. E. Porter (2005): National environmental performance : an empirical analysis of policy results and determinants, in: *Environment and Development Economics* 10 (4), 391–434

EU (European Union) (2000): Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy; online: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:327:0001:0001:EN:PDF (accessed 08 Dec. 2013)

FEEM (Fondazione Eni Enrico Mattei) (2013): FEEM sustainability index; online: http://www.feemsi.org/ (accessed 16 Aug. 2013)

Gall, M. (2007): Indices of social vulnerability to natural hazards : a comparative evaluation, Columbia, SC: University of South Carolina, Department of Geography (PhD dissertation); online: http://webra.cas.sc.edu/hvri/education/docs/Melanie_Gall_2007.pdf (accessed 08 Dec. 2013)

Galli, A. et al. (2012): Integrating ecological, carbon and water footprint into a "Footprint Family" of indicators : definition and role in tracking human pressure on the planet, in: *Ecological Indicators* 16, 100–112

Gawel, E. / K. Bernsen (2013): What is wrong with virtual water trading? : on the limitations of the virtual water concept, in: *Environment and Planning C: Government and Policy* 31 (1), 168–181

Grafton, R. Q. et al. (2012): A dictionary of climate change and the environment : economics, science, and policy, Cheltenham: Edward Elgar Publishing

Groombridge, B. (1992): Global biodiversity : status of the earth's living resources, London: Chapman and Hall

Grunwald, A. / J. Kopfmüller (2012): Nachhaltigkeit, 2. Aufl., Frankfurt: Campus Verlag

Hák, T. (2007): The Yale and Columbia Universities' environmental sustainability index 2005, in: T. Hák / B. Moldan / A. L. Dahl (eds.), Sustainability indicators : a scientific assessment, Washington, DC: Island Press, 361–367 (SCOPE Report 67)

– / B. Moldan / A. L. Dahl (2007): Sustainability indicators : a scientific assessment, Washington, DC: Island Press (SCOPE Report 67)

Heywood, V. H. (1995): Global biodiversity assessment, Cambridge: Cambridge University Press

Jeffries, M. J. (1997): Biodiversity and conservation, London: Routledge

Jha, R. / K. V. Bhanu Murthy (2006): Environmental sustainability : a consumption approach, London: Routledge

Kaly, U. / C. Pratt / J. Mitchell (2004): The environmental vulnerability index (EVI) 2004 (SOPAC Technical Report 384); online: http://islands.unep.ch/EVI%202004%20Technical%20Report.pdf (accessed 08 Dec. 2013)

Kerk, G. van de / A. Manuel (2012): Sustainable society index 2012, The Hague: Sustainable Society Foundation

Kitzes, J. et al. (2007): Current methods for calculating national ecological footprint accounts, in: *Science for Environment and Sustainable Society* 4 (1), 1–9

– / M. Wackernagel (2009): Answers to common questions in ecological footprint accounting, in: *Ecological Indicators* 9 (4), 812–817

Klugman, J. / F. Rodríguez / H.-J. Choi (2011): The HDI 2010 : new controversies, old critiques (Human Development Research Paper 2011/01); online: http://hdr.undp.org/en/reports/global/hdr2011/papers/HDRP_2011_01.pdf (accessed 08 Dec. 2013)

Linster, M. (2003): OECD environmental indicators : development, measurement and use, Paris: OECD (Reference Paper)

Meadows, D. H. et al. (1972): The limits to growth : a report for the Club of Rome's project on the predicament of mankind, New York: Universe Books

Mekonnen, M. M. / A. Y. Hoekstra (2011): National water footprint accounts : the green, blue and grey water footprint of production and consumption : main report, Vol. 1, Delft: UNESCO-IHE Institute for Water Education

Moldan, B. / S. Janoušková / T. Hák (2012): How to understand and measure environmental sustainability : indicators and targets, in: *Ecological Indicators* 17, 4–13

Niemeijer, D. (2002): Developing indicators for environmental policy : data-driven and theory-driven approaches examined by example, in: *Environmental Science & Policy* 5 (2), 91–103

OECD (Organisation for Economic Co-operation and Development) (2008): Handbook on constructing composite indicators : methodology and user guide, Paris

– (2011): Towards green growth, Paris

– (2012a): Glossary of statistical terms; online: http://www.oecd-ilibrary.org/docserver/download/3008121e.pdf?expires=1386528811&id=id&accname=guest&checksum=10867A892C11CCBCA278DAA4AB194DC1 (accessed 08 March 2012)

– (2012b): OECD environmental performance reviews : Germany 2012, Paris

OECD Environment Directorate (2008): OECD key environmental indicators, Paris

Pepper, I. L. / C. P. Gerba / M. L. Brusseau (2006): Environmental and pollution science, 2nd ed., Amsterdam: Elsevier

Pereira, H. M. / H. D. Cooper (2006): Towards the global monitoring of biodiversity change, in: *Trends in ecology & evolution* 21 (3), 123–129

Perman, R. et al. (2011): Natural resource and environmental economics, 4th ed., Harlow: Addison Wesley

Pintér, L. / D. Swanson / J. Chenje (2009): Integrated environmental assessment : training mannual, Nairobi: UNEP (United Nations Environment Programme), IISD (International Institute for Sustainable Development)

Pratt, C. / U. Kaly / J. Mitchell (2004): Manual : how to use the environmental vulnerability index (EVI); online: http://islands.unep.ch/EVI%20Manual.pdf (accessed 08 Dec. 2013)

Prescott-Allen, R. (2001): The wellbeing of nations : a country-by-country index of quality of life and the environment, Washington, DC: Island Press

Rockström, J. et al. (2009): A safe operating space for humanity, in: *Nature* 461 (7263), 472–475

Saisana, M. / S. Tarantola (2002): State-of-the-art report on current methodologies and practices for composite indicator development; online: http://bookshop.europa.eu/en/state-of-the-art-report-on-current-methodologies-and-practices-for-composite-indicator-development-pbEUNA20408/ (accessed 08 Dec. 2013)

– */ M. Nardo / A. Saltelli* (2005): Uncertainty and sensitivity analysis of the 2005 ESI, in: D. C. Esty et al. (eds.), 2005 Environmental sustainability index : benchmarking national environmental stewardship, New Haven, Conn.: Yale Center for Environmental Law and Policy, 75–87

– */ A. Saltelli* (2010): Uncertainty and sensitivity analysis of the 2010 environmental performance index; online: http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/13525/1/reqno_jrc56990_saisana_saltelli_2010epi_eur.pdf%5B1%5D.pdf (accessed 08 Dec. 2013)

– */ –* (2012): Appendix II : preliminary sensitivity analysis, in: J. W. Emerson et al. (eds.), 2012 environmental performance index and pilot trend environmental performance index, New Haven, Conn.: Yale Center for Environmental Law and Policy, 92–97

– */ D. Philippas* (2012): Sustainable society index (SSI) : taking societies' pulse along social, environmental and economic issues, Ispra: Joint Research Centre (JRC), European Commission

Siche, J. R. et al. (2008): Sustainability of nations by indices : comparative study between environmental sustainability index, ecological footprint and the emergy performance indices, in: *Ecological Economics* 66 (4), 628–637

Smeets, E. / R. Weterings (1999): Environmental indicators : typology and overview, Copenhagen: EEA (European Environment Agency)

Smith, S. J. et al. (2011): Anthropogenic sulfur dioxide emissions : 1850–2005, in: *Atmospheric Chemistry and Physics* 11 (3), 1101–1116

UN (United Nations) (1992): Convention on biological diversity, New York

– (2007): Indicators of sustainable development : guidelines and methodologies, 3rd ed., New York: DESA (United Nations Department of Economic and Social Affairs)

– (2010): Framework for the development of environment statistics, New York: United Nations Economic and Social Council, 1–11

UNEP (United Nations Environment Programme) (2011): Towards a green economy : pathways to sustainable development and poverty eradication; online: http://www.unep.org/greeneconomy/Portals/88/documents/ger/ger_final_dec_2011/Green%20EconomyReport_Final_Dec2011.pdf (accessed 16 Dec. 2013)

– (2012): Global environment outlook (GEO5): environment for the future we want, Nairobi

– (2013): Environmental data explorer; online: http://geodata.grid.unep.ch/ (accessed 16 Aug. 2013)

UNSD (UN Statistics Division) (2013): Environmental indicators; online: http://unstats.un.org/unsd/environment/qindicators.htm (accessed 09 Dec. 2013)

Wackernagel, M. / W. Rees (1996): Our ecological footprint : reducing human impact on the earth, Gabriola Island: New Society Publishers

– et al. (2002): Tracking the ecological overshoot of the human economy, in: *Proceedings of the National Academy of Sciences* 99 (14), 9266–9271

WB (World Bank) (2012): Inclusive green growth : the pathway to sustainable development; online: http://siteresources.worldbank.org/EXTSDNET/Resources/Inclusive_Green_Growth_May_2012.pdf (accessed 16 Dec. 2013)

WBGU (German Advisory Council on Global Change) (2011): World in transition : a social contract for sustainability, Berlin *WHO (World Health Organization)* (2010): WHO guidelines for indoor air quality : selected pollutants, Copenhagen: WHO Regional Office for Europe

WWF (World Wide Fund for Nature) / Zoological Society of London / Global Footprint Network / European Space Agency (2012): Living planet report 2012 : biodiversity, biocapacity and better choices; online: http://worldwildlife.org/publications/living-planet-report-2012-biodiversity-biocapacity-and-better-choices (accessed 08 Dec. 2013)

Annex

Annex A: Environmental indicators and environmental indicator sets

Indicators

The ecological footprint, the carbon footprint and the water footprint are cross-country environmental indicators, but they are not indices in the definition employed here.[40] The three indicators are pressure indicators, which may reflect the state of the environment indirectly, but do not measure the state of the environment directly. These indicators do not allow local assignment for damages; imported impacts are assigned to the consumer, not the producer. For instance, environmental damages caused by production processes in China are attributed to the German balance if these Chinese products are consumed in Germany.

The **ecological footprint** measures the load imposed by a given population on nature, reflecting the degree to which the consumption level of a person (or population) is ecologically sustainable (Grafton et al. 2012). It measures the corresponding area of biologically productive land and aquatic ecosystems needed on a continuous basis to produce the resources used and to absorb all wastes discharged by a defined population at a specified material standard of living (Kitzes / Wackernagel 2009; Wackernagel / Rees 1996; Wackernagel et al. 2002).[41] The underlying idea is related to the concept of carrying capacity, defined as "maximum number of individuals, or the biomass of a species, that can be supported by its natural environment" (Grafton et al. 2012, 53). The indicator includes only those aspects of resource consumption and waste production for which nature has regenerative capacity and data exists to express the demand in productive area (WWF et al. 2012). It is based on per capita measures, quantifying the land area need per person (or population). The measurement does not include the ecologically productive land area required to support other species than humans (Wackernagel / Rees 1996). Although mainly used at national level, it can be applied to any scale, including individuals. Yet, the Ecological Footprint does not reflect the intensity with which a biologically productive area is being used (WWF et al. 2012).

The idea of measuring the ecological impact of human activity has been extended to measuring the ecological impact of carbon dioxide emissions, the carbon footprint, as well as to the amount of freshwater used in consumption and production, the water footprint.

The **carbon footprint** is either defined with regard to the volume of greenhouse gas emissions or with regard to the demand on bioproductive area. In the first case, it measures the volume of greenhouse gas emissions that are attributable to human activities over a particular period (Grafton et al. 2012). In the second case, for instance in the LPI, the carbon footprint measures the demand on biocapacity, typically of unharvested forests, to sequester through photosynthesis the carbon dioxide emissions from fossil fuel combustion (WWF et al. 2012). It calculates the natural sequestration necessary to maintain a constant concentration of carbon dioxide in the atmosphere. Subtracting the absorptive capacity of the oceans, the area required to absorb and retain the remaining carbon is calculated based on the average sequestration rate of the global forests.[42]

The **water footprint** measures the volume of freshwater used directly or indirectly in the production of a good or service (Grafton et al. 2012). The water footprint of a product is the equivalent of virtual water, measured at the actual production site as the sum of the water used in the different steps of the production chain (WWF et al. 2012). Rainwater that evaporates during the production of goods is referred to as the

40 The EF is classified as an index in Böhringer / Jochem (2007).

41 Biological productivity or bioproductivity is the ability of a biome to produce biomass above or below the soil surface (Siche et al. 2008, 629).

42 With a portion of 55%, the carbon footprint is the largest component of the ecological footprint (WWF et al. 2012).

Annex A (cont.): Environmental indicators and environmental indicator sets

green water footprint. Freshwater that is withdrawn from surface or groundwater sources but not returned is measured with the blue water footprint. Water used to dilute pollutants of the production process to such an extent that the quality of the ambient water complies with water quality standards is referred to as the grey water footprint.

The carbon footprint and the water footprint follow a similar principle of measurement, but differ in the usefulness of their results. The carbon footprint always reveals information about the impact of an activity on climate change, regardless of the product or the production site; whereas water is a local resource with varying opportunity costs and, therefore, a high water footprint does not disclose whether environmental damages have actually occurred (Gawel / Bernsen 2013).

Indicator sets

The **Global Environmental Outlook** assesses the state and trends of the global environment under the themes of atmosphere, land, water, biodiversity, and chemicals and waste, using the DPSIR analytical framework (UNEP 2012). It identifies and evaluates “the complex and multidimensional cause-and-effect relationships between society and the environment” (UNEP 2012, xix). Key indicators are used to examine progress in relation to internationally agreed goals, based on national, regional and global analyses and datasets. The globally and regionally set goals and targets are compared to the current environmental situation, in order to assess whether they have been met and to determine the size of the gap between the current and the intended situations. The fifth edition (GEO-5) assesses progress towards ninety of the most important environmental goals and objectives, among others. Coverage of developing countries varies for indicators.[43]

The **OECD Core Environmental Indicators** track environmental progress and analyse environmental policies with about 50 core indicators (Linster 2003). Data are provided for all OECD member countries and in some cases for selected non-member economies, including Brazil, China, India, Indonesia, the Russian Federation, and South Africa. According to the pressure-state-response model, the indicators are classified into environmental pressures, environmental conditions and societal responses. The indicators focus either on aspects of environmental quality, on the quantity aspect of natural resources, or on background variables. Selected key environmental indicators (KEI) from the core indicators serve communication purposes to the general public and policy-makers. These indicators were selected based on their policy relevance, analytical soundness and measurability, subject to change in the future.[44] The key indicators focus on pollution and natural resources. Sectoral environmental indicators (SEI) help integrate environmental concerns into sectoral decisions. They are not restricted to environmental indicators but consider linkages between the environment, economy and society, placed in the context of sustainable development.[45]

The **European Environment Agency core set indicators** (EEA 2005) contain 37 indicators, which cover six environmental themes (air pollution and ozone depletion, climate change, waste, water, biodiversity and terrestrial environment) and four sectors (agriculture, energy, transport and fisheries). Among other things, they aim at assessing progress against environmental policy priorities in the EU. Each indicator can be clas-

43 The underlying dataset is freely accessible (UNEP 2013).

44 Indicators of toxic contamination, land and soil resources, and urban environmental quality are expected to be included as well (OECD Environment Directorate 2008, 9).

45 These indicators are used for OECD Environmental Performance Reviews which assess a country’s progress in achieving domestic and international environmental policy commitments and provide policy recommendations (e.g. OECD 2012b). The reviews use a lot of economic, social and environmental data, but no indicators and no composite indicator is constructed.

Annex A (cont.): Environmental indicators and environmental indicator sets

sified by the DPSIR framework, but the five categories of DPSIR are not represented in a balanced and comprehensive way. All of the indicators are either descriptive indicators or performance indicators.[46]

The **Commission on Sustainable Development Indicators of Sustainable Development** are thought to provide a sample set for countries to be used to track progress toward nationally defined goals and sustainable development. The last revision contains a core set of 50 indicators, being part of a large set of 96 indicators on sustainable development. The larger set enables the inclusion of other indicators that allow for a more comprehensive and differentiated assessment of sustainable development. Core indicators are relevant for sustainable development in most countries, provide information not available from other core indicators, and can be calculated with data either readily or easily available (UN 2007). The social, economic, environmental and institutional pillars are no longer explicitly mentioned in the newly revised set. Instead, the core indicators and the additional other indicators are arranged in cross-cutting themes: poverty, governance, health, education, demographics, natural hazards, atmosphere, land, oceans, seas and coasts, freshwater, biodiversity, economic development, global economic partnership, and consumption and production patterns. The CSD Indicators of Sustainable Development is a national-oriented set that can include indicators lacking adjustment for cross-country comparisons or lacking time-series data (UN 2007).

UNSD (UN Statistics Division) Environmental Indicators provide global environment statistics on ten indicators (air and climate; biodiversity; energy and minerals; forests; governance; inland water resources; land and agriculture; marine and coastal areas; natural disasters, waste) (UNSD 2013). Selected indicators have a relatively good quality and geographic coverage.

46 The current database is available online (EEA 2013).

Annex B: Comparison of indicators

Name	**Ecological footprint**	**Water footprint**	**Carbon footprint**
Source	Borucke et al. 2013	Galli et al. 2012, Mekonnen and Hoekstra 2011	Galli et al. 2012
Developer(s)	Wackernagel and Rees	Mekonnen and Hoekstra	?
Concept measured	Ecological impact of humanity	Total freshwater use to produce goods and services	Total greenhouse gas emissions (GHG) caused by goods and services
Description	– Resource and emission accounting tool to measure the load imposed on nature by a given population – Resource flow measure	– Direct and indirect water use of a consumer or producer – Links human consumption and water use	Greenhouse gases that are directly and indirectly caused by human activities or accumulated over the life stages of products
Main dimensions	Corresponding area of productive land and aquatic ecosystems needed to produce the resources used and assimilate the wastes produced by a defined population at a specified material standard of living, wherever on earth that may be located	The human appropriation of the volume of freshwater required to produce goods and services	Total amount of six greenhouse gases (CO_2, CH_4, N_2O, HFC, PFC, and SF_6) measured in mass units
Year(s) of publication	2012	?	?
Country coverage (no. of developing countries (DCs))	200 countries (based on LPI 2012 report) (113 DCs)	? (134 DCs)	197 countries (139 DCs)
No. of indicators	Not fixed	?	?
Environmental spheres	Land, oceans	Water	Climate
	National		
1. Data selection	?	?	?
2. Imputation of missing data	?	?	?
3. Normalisation	Transformation in square km	Water volumes consumed and polluted per unit of time	No conversion to an area unit

Annex B (cont.): Comparison of indicators

Name	**Ecological footprint**	**Water footprint**	**Carbon footprint**
4. Weighting	Equal	?	?
5. Aggregation methods	Adding up all land and water requirements	Adding up all water requirements	Adding up greenhouse gas emissions
6. Multivariate analysis	?	?	?
7. Uncertainty and sensitivity	–	–	?
8. Decomposition	–	?	?
9. Links to other indices	–	?	?
10. Visualisation of results	(in Living Planet Index)	Maps	Maps
Comments	– Provides a snapshot of past resource demand and availability – Monitors combined impact of anthropogenic pressures – Deals with important aspects of sustainability (carrying capacity, over consumption, biocapacity) – Emphasises effects of exported impacts – Reflects the degree to which consumption level is ecologically sustainable	– Applies the idea of resource use to water	– Offers an alternative angle for international policy on climate change – Allows fo a comprehensive assessment of human contribution to GHG emissions – Consistent with standards of economic and environmental accounting – Consistent emissions data available for most countries
Strengths	– Used mainly at the national level but can be applied at any scale, including individuals – Strongly communicative on public and policy levels – Used by scientific community and the media	– Used mainly at the national level but can be applied at any scale, including individuals – Represents the spatial distribution of a nation's water 'demand' – Expands traditional measure of water withdrawal	– Used mainly at the national level but can be applied at any scale, including individuals – Always reveals information about impact of activity on climate change
Weaknesses	– Underlying information is less accessible, due to high level of aggregation – Does not reflect intensity with which productive area is being used	– Does not disclose whether environmental damages have actually occurred – Weak theoretical background – Relies on local data frequently unavailable and/or hard to collect	– Cannot track full range of human demands on the environment

Source: Own elaboration

Annex C: Comparison of indicator sets

Name	Global Environmental Outlook (GEO) indicators	OECD Core Environmental Indicators (CEI)	CSD Indicators of Sustainable Development	European Environment Agency (EEA) core set indicators	UNSD Environmental Indicators
Source	UNEP 2012	Linster 2003	UN 2007	EEA 2005	UNSD webpage
Description	Informs about the state and trends of the global environment.	Indicators are classified into environmental pressures, environmental conditions, and societal responses. Sub-groups of key indicators or sectoral environmental indicators possible.	A sample set for countries for tracking progress toward nationally defined goals and sustainable development.	Six environmental themes and four sectors to assess progress against environmental policy priorities in the EU	Global environment statistics on wide range of environmental topics
Main dimensions	1) Atmosphere, 2) Land, 3) Water, 4) Biodiversity, 5) Chemicals and waste	1) Environmental quality, 2) Quantity aspect of natural resources	1) Poverty, 2) Governance, 3) Health, 4) Education, 5) Demographics, 6) Natural hazards, 7) Atmosphere, 8) Land, 9) Oceans, seas and coasts, 10) Freshwater, 11) Biodiversity, 12) Economic development, 13) Global economic partnership, 14) Consumption and production patterns	Ozone depletion, biodiversity, climate change, terrestrial, waste, water, agriculture, energy, fisheries, transport	Air and climate; biodiversity; energy and minerals; forests; governance; inland water resources; land and griculture; marine and coastal areas; natural disasters, waste
Year(s) of publication	2012 (next update 2014)	–	–	–	–
Country coverage (no. of developing countries (DCs))	Not uniform; depends on variable	OECD member countries; 6 DCs (Brazil, China, India, Indonesia, Russian Federation, South Africa)	?	31 European countries: EU–27 plus EFTA–4 (Iceland, Liechtenstein, Switzerland and Norway)	Not uniform; depends on variable
No. of indicators	-	about 50 indicators	50 indicators (core set)	37 indicators	> 32 indicators

Annex C (cont.): Comparison of indicator sets

Name	**Global Environmental Outlook (GEO) indicators**	**OECD Core Environmental Indicators (CEI)**	**CSD Indicators of Sustainable Development**	**European Environment Agency (EEA) core set indicators**	**UNSD Environmental Indicators**
No. of variables	> 500 variables	–	–	–	–
Environmental spheres	Presumably all, except weather	All environmental spheres, except weather	Air, climate, land, forests, water, (rivers), oceans, fisheries, waste, biodiversity	Air, climate, land, soil, water, rivers, oceans, fisheries, waste, biodiversity	(Weather), air, climate, land, (soil), forests, water, (oceans), waste, biodiversity
Comments	Highlights key global and regional environmental issues and assesses progress in terms of most important (global) environmental objectives	Indicators focus on environmental quality, quantity aspect of natural resources, or background variables	– Social, economic, environmental, institutional pillars are no longer mentioned, but indicators are arranged in cross-cutting themes such as natural hazards, atmosphere, land, oceans etc. – National-oriented dataset	Developed for EU countries	Compilation of global environment statistics from a wide range of data sources
Strengths	–	Widely used by organisations and scientific community	–	–	–
Weaknesses	–	Does not include developing countries, except for some emerging economies	–	Does not include developing countries	–

Source: Own elaboration

Annex D: Coverage of environmental spheres

	Environmental sphere										Cross-cutting issues			Link to human wellbeing
	Atmosphere			Lithosphere			Hydrosphere							
	Weather	Air	Climate	Land	Soil	Forests	Water	Rivers	Oceans	Fisheries	Chemicals	Waste	Biodiversity	Environmental health
Index														
Ecosystem Wellbeing Index		x	x	x	x	x	x	x (river conversion)		x	x (water)		x	
Environmental Performance Index		x	x	x (agricultural subsidies)		x	x	x (water quantity)		x	x (pesticide regulation)		x	x
Environmental Sustainability Index		x	x	x	x	x	x			x		x	x	x
Environmental Vulnerability Index	x	x		x		x (vege-tation)	x			x	x (hazardous substances)	x	x	
Environmental Wellbeing (Sustainable Society Index)		x	x				x						x	
Living Planet Index													x	
Indicator														
Ecological Footprint			x	x	x	x				x				
Carbon Footprint			x											
Water Footprint							x							

Annex D (cont.): **Coverage of environmental spheres**

	Environmental sphere										**Cross-cutting issues**			**Link to human wellbeing**
	Atmosphere			**Lithosphere**			**Hydrosphere**							
	Weather	Air	Climate	Land	Soil	Forests	Water	Rivers	Oceans	Fisheries	Chemicals	Waste	Biodiversity	Environmental health
Indicator set														
CSD Indicators of Sustainable Development		x	x	x		x	x	(x)	x	x		x	x	
European Environment Agency (EEA) core set indicators		x	x	x	x		x	x	x	x		x	x	
Global Environment Outlook (GEO) indicators		(x)	x	x	x	x	x	x	x	x	x	x	x	x
OECD Core Environmental Indicators (CEI)		x	x	x	x	x	x	(x)	(x)	x	(x)	x	x	(x)
UNSD (UN Statistics Division) Environmental Indicators	x (natural disasters)	x	x	x	x (agri-culture)	x	x		x (marine and coastal areas)			x	x	

Source: Own elaboration

Annex E: Geographical coverage of developing countries

	Region (United Nations)	Country	Ecosystem Wellbeing Index	Environmental Performance Index	Environmental Sustainability Index	Environmental Vulnerability Index	Environmental Wellbeing (SSI)
1	Africa	Algeria	x	x	x	x	x
2		Djibouti	x			x	
3		Egypt, Arab Rep.	x	x	x	x	x
4		Libya	x	x	x	x	x
5		Morocco	x	x	x	x	x
6		Tunisia	x	x	x	x	x
7		Angola	x	x	x	x	x
8		Benin	x	x	x	x	x
9		Botswana	x	x	x	x	x
10		Burkina Faso	x		x	x	x
11		Burundi	x		x	x	x
12		Cameroon	x	x	x	x	x
13		Cape Verde	x			x	
14		Central African Republic	x		x	x	x
15		Chad	x		x	x	x
16		Comoros	x			x	
17		Congo, Dem. Rep.	x	x	x	x	x
18		Congo, Rep.	x	x	x	x	x
19		Côte d'Ivoire	x	x	x	x	x
20		Eritrea	x	x		x	
21		Ethiopia	x	x	x	x	x
22		Gabon	x	x	x	x	x
23		Gambia, The	x		x	x	x
24		Ghana	x	x	x	x	x
25		Guinea	x		x	x	x
26		Guinea-Bissau	x		x	x	x
27		Kenya	x	x	x	x	x
28		Lesotho	x			x	
29		Liberia	x		x	x	x
30		Madagascar	x		x	x	x
31		Malawi	x		x	x	x
32		Mali	x		x	x	x
33		Mauritania	x		x	x	x
34		Mauritius	x			x	
35		Mozambique	x	x	x	x	x
36		Namibia	x	x	x	x	x

Annex E (cont.): Geographical coverage of developing countries

	Region (United Nations)	Country	Ecosystem Wellbeing Index	Environ-mental Performance Index	Environ-mental Sustainability Index	Environ-mental Vulnerability Index	Environ-mental Wellbeing (SSI)
37	Africa	Niger	x		x	x	x
38		Nigeria	x	x	x	x	x
39		Rwanda	x		x	x	x
40		São Tomé and Principe	x			x	
41		Senegal	x	x	x	x	x
42		Seychelles	x			x	
43		Sierra Leone	x		x	x	x
44		Somalia	x			x	
45		South Africa	x	x	x	x	x
46		South Sudan	NA	NA	NA	NA	NA
47		Sudan	x	x	x	x	x
48		Swaziland	x			x	
49		Tanzania	x	x	x	x	x
50		Togo	x	x	x	x	x
51		Uganda	x		x	x	x
52		Zambia	x	x	x	x	x
53		Zimbabwe	x	x	x	x	x
54	America	Antigua and Barbuda	x			x	
55		Argentina	x	x	x	x	x
56		Belize	x			x	
57		Bolivia	x	x	x	x	x
58		Brazil	x	x	x	x	x
59		Chile	x	x	x	x	x
60		Colombia	x	x	x	x	x
61		Costa Rica	x	x	x	x	x
62		Cuba	x	x	x	x	x
63		Dominica	x				
64		Dominican Republic	x	x	x	x	x
65		Ecuador	x	x	x	x	x
66		El Salvador	x	x	x	x	x
67		Grenada	x			x	
68		Guatemala	x	x	x	x	x
69		Guyana	x		x	x	x
70		Haiti	x	x	x	x	x
71		Honduras	x	x	x	x	x
72		Jamaica	x	x	x	x	x
73		Mexico	x	x	x	x	x
74		Nicaragua	x	x	x	x	x

Annex E (cont.): Geographical coverage of developing countries

	Region (United Nations)	Country	Ecosystem Wellbeing Index	Environ-mental Performance Index	Environ-mental Sustainability Index	Environ-mental Vulnerability Index	Environ-mental Wellbeing (SSI)
75	America	Panama	x	x	x	x	x
76		Paraguay	x	x	x	x	x
77		Peru	x	x	x	x	x
78		St. Lucia	x			x	
79		St. Vincent and the Grenadines	x			x	
80		Suriname	x			x	
81		Uruguay	x	x	x	x	x
82		Venezuela, RB	x	x	x	x	x
83	Asia	Cambodia	x	x	x	x	x
84		China	x	x	x	x	x
85		Indonesia	x	x	x	x	x
86		Korea, Dem. Rep.	x		x	x	x
87		Lao PDR	x		x	x	x
88		Malaysia	x	x	x	x	x
89		Mongolia	x	x	x	x	x
90		Myanmar	x	x	x	x	x
91		Philippines	x	x	x	x	x
92		Thailand	x	x	x	x	x
93		Timor-Leste					
94		Vietnam	x	x	x	x	x
95		Afghanistan	x			x	
96		Bangladesh	x	x	x	x	x
97		Bhutan	x		x	x	x
98		India	x	x	x	x	x
99		Maldives	x			x	
100		Nepal	x	x	x	x	x
101		Pakistan	x	x	x	x	x
102		Sri Lanka	x	x	x	x	x
103		Armenia	x	x	x	x	x
104		Azerbaijan	x	x	x	x	x
105		Georgia	x	x	x	x	x
106		Kazakhstan	x	x	x	x	x
107		Kyrgyz Republic	x	x	x	x	x
108		Tajikistan	x	x	x	x	x
109		Turkey	x	x	x	x	x
110		Turkmenistan	x	x	x	x	x
111		Uzbekistan	x	x	x	x	x

Annex E (cont.): Geographical coverage of developing countries

	Region (United Nations)	Country	Ecosystem Wellbeing Index	Environ-mental Performance Index	Environ-mental Sustainability Index	Environ-mental Vulnerability Index	Environ-mental Wellbeing (SSI)
112		Iran, Islamic Rep.	x	x	x	x	x
113		Iraq	x	x	x	x	x
114		Jordan	x	x	x	x	x
115		Lebanon	x	x	x	x	x
116		Syrian Arab Republic	x	x	x	x	x
117		West Bank and Gaza					
118		Yemen, Rep.	x	x	x	x	x
119	Europe	Albania	x	x	x	x	x
120		Belarus	x	x	x	x	x
121		Bosnia and Herzegovina	x	x	x	x	x
122		Bulgaria	x	x	x	x	x
123		Kosovo					
124		Latvia	x	x	x	x	x
125		Lithuania	x	x	x	x	x
126		Macedonia, FYR	x	x	x	x	x
127		Moldova	x	x	x	x	x
128		Montenegro			x*		x
129		Romania	x	x	x	x	x
130		Russian Federation	x	x	x	x	x
131		Serbia		x	x		x
132		Ukraine	x	x	x	x	x
133	Oceania	American Samoa				x	
134		Fiji	x			x	
135		Kiribati				x	
136		Marshall Islands				x	
137		Micronesia, Fed. Sts.				x	
138		Palau				x	
139		Papua New Guinea	x		x	x	x
140		Samoa	x			x	
141		Solomon Islands	x			x	
142		Tonga	x			x	
143		Tuvalu				x	
144		Vanuatu	x			x	

Notes: Only developing countries (non-high-income countries) are included (light blue = low income; darker blue = lower middle income; darkest blue = upper middle income). Income definition according to World Bank. Region definition according to United Nations. Always last edition of each index. x* = counted as part of Serbia.

Source: Own elaboration

Publications of the German Development Institute

Studies

78 *Reeg, Caroline:* Micro, Small and Medium Enterprise Upgrading in India: learning from success cases, 299 pp., Bonn 2013, ISBN 978-88985-585-5

77 *Mahn, Timo:* Country-Level Aid Coordination at the United Nations – Taking the Resident Coordinator System Forward, 146 pp., Bonn 2013, ISBN 978-3-88985-584-8

76 *Loewe, Markus et al.:* Which Factors Determine the Upgrading of Small and Medium-Sized Enterprises (SMEs)? The case of Egypt, 288 pp., Bonn 2013, ISBN 978-3-88985-583-1

75 *Mallik, Vidyadhar:* Local and Community Governance for Peace and Development in Nepal, 179 pp., Bonn 2013, ISBN 978-3-88985-582-4

74 *Brandi, Clara et al.:* Sustainability Certification in the Indonesian Palm Oil Sector: Benefits and challenges for smallholders, 258 pp., Bonn 2013, ISBN 978-3-88985-581-7

73 *Klingebiel, Stephan:* Entwicklungszusammenarbeit – eine Einführung, 86 pp., Bonn 2013, ISBN 978-3-88985-580-0

[Price: EUR 10.00; books may be ordered from the DIE or through bookshops.]

Discussion Papers

24/2013 *Zulueta-Fülscher, Kimana:* Contributing to democratic consolidation and sustainable peace in El Salvador and the Philippines. Overcoming the quest for stability, 33 pp., Bonn 2013, ISBN 978-3-88985-607-4

23/2013 *Burchi, Francesco:* Women's political role and poverty in the educational dimension. A district-level analysis in India, 27 pp., Bonn 2013, ISBN 978-3-88985-605-0

22/2013 *Wennubst, Pio / Timo Casjen Mahn:* A Resolution for a Quiet Revolution: taking the United Nations to sustainable development 'beyond aid', 50 pp., Bonn 2013, ISBN 978-3-88985-603-6

21/2013 *Hampel-Milagrosa, Aimée / Markus Loewe / Caroline Reeg:* Which Factors Determine the Upgrading of Micro, Small and Medium-Sized Enterprises? Evidence from Egypt, India and the Philippines, 24 pp., Bonn 2013, ISBN 978-3-88985-604-3

20/2013 *Schmitz, Birgit:* Macroprudential Financial Market Regulation, 38 pp., Bonn 2013, ISBN 978-3-88985-602-9

[Price: EUR 6.00; books may be ordered from the DIE or through bookshops.]

A complete list of publications available from the DIE can be found at:
http://www.die-gdi.de